

ARMY RESEARCH LABORATORY



Assessment to Determine the Thermal
Protective Capability of the U.S.
Marine Corps Modular Sleeping Bag

Charles A. Hickey, Jr.
Lavern L. Petersen

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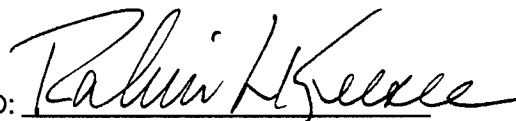
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ASSESSMENT TO DETERMINE THE THERMAL PROTECTIVE CAPABILITY
OF THE U.S. MARINE CORPS MODULAR SLEEPING BAG

Charles A. Hickey, Jr.
Lavern L. Petersen

November 1994

APPROVED:



ROBIN L. KEESEE
Executive, Human Research &
Engineering Directorate

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ASSESSMENT TO DETERMINE THE THERMAL PROTECTIVE CAPABILITIES OF THE USMC MODULAR SLEEPING BAG (MSB)

INTRODUCTION

The United States Marine Corps (USMC) Systems Command (MARCORSYSCOM) prepared a commercial item description (MARCORSYSCOM-CID-93-A-A-50603) for a modular sleeping bag (MSB) in March 1993. The item description specified that the modular sleeping bag be a two-sleeping-bag system capable of providing thermal protection for its users at a range of environmental temperatures. This system comprises a lightweight patrol bag and an intermediate cold weather bag. The patrol bag is for use in temperate climates where temperatures range from +50° to +30° F. The intermediate cold weather bag is for use in colder climates where temperatures range from +30° to 0° F. The item description also specified that the intermediate sleeping bag must fit inside the patrol bag to make an extreme cold weather sleeping bag capable of providing thermal protection for users at temperatures from 0° to -30° F. Nine different modular sleeping bag candidates were submitted to USMC from various manufacturers.

USMC asked various Government agencies to assess the candidate modular sleeping bags. The Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) conducted assessments to determine the thermal protective capabilities of the candidate modular sleeping bags at -30° F. The results of this assessment, as well as those of other agencies, were compiled by USMC. These results were used in a down selection process to determine the most viable candidates. Manufacturers of the candidate modular sleeping bags were given the opportunity to correct the design shortcomings noted with their candidate system and to participate in a bidding process for the selection of a modular sleeping bag. A contract for a modular sleeping bag was awarded in November 1993.

MARCORSYSCOM asked HRED to conduct controlled cold chamber trials for each sleeping bag configuration of the modular sleeping bag selected. In addition, HRED was asked to conduct subjective evaluations for the modular sleeping bag during user field trials conducted during the winter of 1994. These tests were conducted from January through March 1994. Twelve marines participated in controlled cold chamber trials, and approximately 550 marines participated in user field trials.

The results of the cold chamber trials indicated that none of the sleeping bag configurations provided adequate thermal protection to afford users with 4 hours of comfortable rest or sleep at the ambient air temperatures required. In fact, the marines who participated were only comfortable during trials when the air temperatures were 10° to 15° warmer than required. The data collected during the daily debriefings (comments made by marine subjects after each cold chamber trial) enabled the experimenters to detect the design shortcomings in the modular sleeping bag. The results of the subjective evaluations conducted during the user field trials show that most of the marines rated the modular sleeping bag favorably and considered it to be better than the current bag. However, the ratings and recommendations made by these marines identified similar, if not identical, design shortcomings. The modular sleeping bag was subsequently redesigned to correct the design shortcomings that were determined during these trials.

After the modular sleeping bag was redesigned, USMC again asked HRED to conduct controlled cold chamber trials to assess the thermal protective capabilities for each sleeping bag configuration. Trials were conducted to assess the patrol, intermediate, and the extreme cold sleeping bag configurations. The trials were conducted in an environmental cold chamber in Building 362, Aberdeen Proving Ground, Maryland, from 6 June to 1 July 1994.

OBJECTIVES

The purpose of this assessment was to determine the lowest ambient air temperatures at which the patrol, intermediate, and extreme cold weather sleeping bag configurations will provide adequate thermal protection to afford its users with 4 hours of comfortable rest or sleep, and to identify any human factors or design shortcomings.

SUBJECTS

Twelve marines served as test subjects in this study. Four marines were from the Marine Corps Base, Camp LeJeune, North Carolina, and eight marines were from the Marine Corps Base, Quantico, Virginia. Eleven marines were males and one was a female.

Subject Groups

The marines were divided into three separate groups of four each because the environmental chamber could only accommodate 4 subjects at a time. The first group (Subjects 1 through 4) participated in trials from 6 to 17 June 94. The second and third groups (Subjects 5 through 8 and 9 through 12, respectively) participated in trials from 20 June through 1 July 94.

Medical Screening

The medical records of these marines were reviewed by U.S. Navy medical officers. These reviews assured that none of the marines had a history of cold intolerance or cold injury, alcoholism, or circulatory disorder. These reviews also determined that none of the marines were receiving or had recently received medications that would interfere with temperature regulation or shivering.

Volunteer Consent

Before the cold chamber trials began, the subjects were given an orientation about the purpose of the trials and their participation. After the briefing, the marines were given volunteer consent affidavits to read. After reading the affidavits, the marines were given the opportunity to ask and have answered all questions pertaining to the test and their participation. The marines were then asked to complete and sign the affidavits (see Appendix A) if they volunteered to participate.

Anthropometry

The anthropometric measurements of stature, bideltoid breadth, shoulder circumference, waist (omphalic) circumference, and hip circumference were made on these marines. The measurements and corresponding percentile values are shown in Table 1. The percentile values for these measurements were taken from the most recent survey data (Gordon et al., 1989). Subject 9 was a female and her percentile values were taken from the female data reported in the survey.

Table 1
Anthropometric Measurements of Subjects

| Subject No. | <u>Stature</u> | | <u>Bideltoid breadth</u> | | <u>Shoulder circumference</u> | | <u>Waist circumference</u> | | <u>Hip^a circumference</u> |
|----------------|----------------|------------|--------------------------|------------|-------------------------------|------------|----------------------------|------------|--------------------------------------|
| | cm | percentile | cm | percentile | cm | percentile | cm | percentile | cm |
| 1 | 167.5 | 11th | 42.6 | 1st | 104.6 | 1st | 67.2 | 1st | 82.3 |
| 2 | 186.0 | 94th | 49.4 | 55th | 121.4 | 75th | 86.0 | 52nd | 96.1 |
| 3 | 190.1 | 98th | 49.8 | 60th | 120.6 | 70th | 86.0 | 52nd | 100.5 |
| 4 | 172.3 | 30th | 49.8 | 60th | 124.5 | 88th | 82.6 | 37th | 96.8 |
| 5 | 171.7 | 29th | 47.9 | 32nd | 110.8 | 13th | 72.5 | 4th | 93.2 |
| 6 | 174.5 | 43rd | 50.6 | 71st | 130.5 | 98th | 88.5 | 62nd | 103.5 |
| 7 | 175.2 | 48th | 48.7 | 44th | 118.2 | 55th | 76.9 | 14th | 90.1 |
| 8 | 183.1 | 88th | 49.7 | 60th | 120.4 | 69th | 86.0 | 52nd | 102.1 |
| 9 ^b | 153.4 | 7th | 42.1 | 31st | 97.2 | 14th | 68.5 | 7th | 95.0 |
| 10 | 170.3 | 23rd | 45.1 | 6th | 110.5 | 12th | 72.0 | 4th | 94.3 |
| 11 | 170.7 | 24th | 47.6 | 29th | 113.4 | 25th | 82.5 | 36th | 95.6 |
| 12 | 167.7 | 11th | 46.6 | 16th | 117.8 | 51st | 93.2 | 78th | 100.3 |

^aHip circumference was not measured in 1988 Anthropometric Survey; no percentile values.

^bFemale: Percentile values correspond to female data listed in 1988 Anthropometric Survey.

TEST ITEMS

The modular sleeping bag is a two-sleeping-bag system as described in the introduction section of this report. The modular sleeping bags evaluated were improved versions (redesigned to correct previous shortcomings) of the Model 300 MSB manufactured by Tennier Industries, Incorporated. The MSB also has a protective bivouac cover and a compressible stuff sack, but neither one was required for these tests. Photographs of each sleeping bag configuration are illustrated in Appendix B.

APPARATUS

Clothing and Equipment

The clothing worn by the subjects during each sleeping bag configuration is shown in Table 2. The extreme cold weather mitten set was worn on the subjects' feet for trials in the extreme cold weather sleeping bag configuration. In addition to clothing, the long model version of the Therm•a•Rest® sleeping pad (Cascade Designs, Inc.) was placed under the sleeping bag for all trials.

Table 2

Clothing Items Worn for Each Sleeping Bag Configuration

| Clothing items worn | <u>Sleeping Bag Configurations</u> | | |
|--------------------------------------------|------------------------------------|-----------------------|------------------|
| | Patrol bag | Intermediate cold bag | Extreme cold bag |
| Expedition weight polypropylene undershirt | • | • | • |
| Expedition weight polypropylene underpants | • | • | • |
| Cold weather wool balaclava (USMC) | • | • | • |
| Cushion sole socks, 50% wool 50% cotton | • | | |
| Fox River Alturas polypropylene undersock | | • | • |
| Seneca red jacket polypro-wool socks | | • | • |
| Extreme cold weather mitten set (on feet) | | | • |

Instrumentation

Body temperatures were measured using Series 400 Yellow Springs Instrument (YSI) Co., Inc., thermistors hardwired to a computer-controlled data acquisition control unit (Hewlett-Packard 3197A) configured to read YSI thermistors. The thermistors for each subject were harnessed and identified so that any given thermistor was always used at the same body location on each individual subject for each trial. Body temperatures were measured at the following locations:

- a. Rectal (core) temperatures were measured using a YSI 401 general purpose thermistor (esophageal or rectal temperature) inserted to a depth of 10 cm.
- b. Back temperatures were measured using a YSI 409B surface temperature thermistor mounted on the skin of the back medial to and slightly below the center of the right scapula.
- c. Fingertip temperatures were measured using a YSI 409B surface temperature thermistor mounted on the palmar surface of the middle finger of the right hand.
- d. Toe temperatures were measured using a YSI 409B surface temperature thermistor mounted on the inside surface of the large toe of the right foot.

A complete set of temperatures was recorded for all subjects at 1-minute intervals for the duration of the exposure period for each trial.

Test Facility

An environmental test chamber in Building 362, Aberdeen Proving Ground, Maryland, was used for this test. The temperature of the chamber was maintained within $\pm 1^\circ$ of its set point for all trials.

PROCEDURES

The first subject group (Subjects 1 through 4) participated in a series of 4-hour cold chamber trials to establish the lowest ambient air temperatures at which the patrol, the intermediate, and the cold weather sleeping bag configurations would provide them adequate thermal protection. The starting ambient air temperature for the initial trial for each sleeping bag configuration was determined by the experimenters and was based on data collected during previous evaluations of the modular sleeping bag. If all subjects passed the initial trial at a given temperature, the chamber temperature was lowered by 10° F increments until at least one subject failed a trial. The chamber temperature was then increased by 5° F and the test repeated. If one or more subjects failed the initial trial, the chamber temperature was raised in 10° F increments until all subjects passed; then, a final test conducted with the chamber decreased by 5° F. This procedure was repeated until the air temperature was bracketed for each sleeping bag configuration. The second and third subject groups (Subjects 5 through 8 and Subjects 9 through 12) participated in 4-hour cold chamber trials at the ambient air temperatures established for each sleeping bag configuration by the first subject group.

A subject was removed from the chamber before the end of the exposure period if he or she had any skin surface temperature that fell below 50° F, if he or she experienced involuntary continuous shivering for 5 minutes or longer, or if the core or rectal temperature fell to 95° F.

The modular sleeping bag (each sleeping bag configuration) was considered acceptable at a specific ambient air temperature if the subjects were able to maintain surface skin temperatures of 50° F or greater, a core (rectal) temperature of 95° F or greater, and if they stated during the debriefing that they slept or rested comfortably for the entire exposure period.

Scenario

Each morning, the subjects arrived at the test facility and received their assigned wiring harness and clothing. The subjects then went to a changing area (rest room), removed their clothing, inserted their rectal thermistors, and put on their polypropylene undershirt and underpants. The experimenters then emplaced the back, finger, and toe thermistors on each subject and performed a pre-test examination to assure that all thermistors and the data acquisition equipment were functional. When completed, the subjects were instructed to put on the rest of their clothing. After all subjects were instrumented and dressed, they promptly entered the sleeping bags inside the cold chamber. Each subject zipped the sleeping bag closed and adjusted the hood on the sleeping bag while an experimenter connected the thermistor leads to the data acquisition system. After all thermistors were connected, the trial was initiated and the subjects remained in the sleeping bags and tried to sleep or rest comfortably for the 4-hour exposure period. All body measurements were recorded at 1-minute intervals throughout the exposure period. The experimenters observed the subjects during this period through a window in the chamber door. Once the trial began, the experimenters did not enter the chamber unless signaled by a subject or unless they felt the need to check the subjects. After the end of the trial, the subjects participated in a debriefing session. They were specifically asked if they were able to rest comfortably or sleep for the entire exposure period.

They were also asked to identify cold spots or if they felt any cold air seeping into the bag at any location. In addition, the subjects were given the opportunity to make comments about the features and characteristics of the sleeping bag (i.e., operation of zippers, drawstrings, size, length, width, comfort, etc.).

TEST DESIGN

Independent Variables

The independent variables were the three sleeping bag and clothing configurations and the cold chamber ambient air temperatures, ranging from +35° F to -30° F.

Dependent Variables

The dependent variables were rectal (core) temperatures, skin surface temperatures, time involuntary continuous shivering occurs, debriefing responses, and experimenter observations.

Hypotheses

A specific hypothesis was not applicable insofar as formal hypotheses are concerned. The purpose was to determine the lowest ambient air temperature that provided all users adequate thermal protection for a 4-hour exposure period for each sleeping bag configuration. The principal datum yielded by each test was either yes, the sleeping bag configuration was adequate at a given temperature level, or no, it was not.

Acceptance Criteria

The criteria for the success of an individual trial were based on the subject's ability to maintain surface skin temperatures of 50° F or greater, a core temperature of 95° F or greater, and if the subject stated that he or she was able to sleep or rest comfortably for the entire exposure period. A modular sleeping bag configuration (sleeping bag and clothing ensemble) was considered acceptable at a specific ambient air temperature if at least 90% of the subject group successfully met this criterion (acceptance criteria as specified in the test and evaluation master plan for the USMC modular sleeping bag).

RESULTS AND DISCUSSION

The ambient air temperatures established by the first subject group (and subsequently used by all subject groups) were +30° F for the patrol bag, 0° F for the intermediate bag, and -30° F for the cold weather sleeping bag. The data presented herewith are only those that pertain to the lowest ambient air temperatures established for each sleeping bag configuration. The results of this assessment determined that the improved version of the modular sleeping bag afforded the subjects (Subjects 1 through 12) with 4 hours of comfortable rest or sleep at an ambient air temperature of +30° F in the patrol bag configuration, at an ambient air temperature of 0° F in the intermediate cold sleeping bag configuration, and at an ambient air temperature of -30° F in the extreme cold sleeping bag configuration.

Graphs of all the temperature versus time data recorded for each sleeping bag configuration are shown in Appendix C. Each graph shows the body temperature data for a given subject in a given sleeping bag configuration. The feet (toes) were the only skin temperatures that cooled enough to even approach 50° F; however, no subject cooled to this temperature during any of the trials. The toe temperatures were recorded for each subject at 1-minute intervals during each 4-hour trial. The toe temperatures noted at the end of each hour for each subject in each sleeping bag configuration are shown in Tables 3 through 5. For subjects lightly dressed and entering a sleeping bag, a substantial amount of time is required to readjust the heat flow gradient between themselves and the bag. Other studies indicate (vanDilla, 1949) that this period of adjustment requires about 60 minutes. For this reason, only the temperatures recorded the last 3 hours were used to determine the rates of temperature change per hour.

Table 3

Toe Temperatures Noted by Hour for Trials at +30° F for the Patrol Sleeping Bag

| Subject No. | Toe Temperatures in Degrees F | | | | $\Delta T/hr$ |
|----------------|-------------------------------|----------|----------|----------|---------------|
| | 60 min. | 120 min. | 180 min. | 240 min. | |
| 1 | 94.4 | 92.8 | 81.2 | 71.5 | 7.6 |
| 2 | 94.9 | 89.9 | 86.5 | 78.7 | 5.4 |
| 3 | 70.7 | 70.9 | 67.8 | 64.2 | 2.2 |
| 4 | 92.9 | 90.3 | 80.8 | 76.2 | 5.6 |
| 5 | 82.0 | 72.5 | 68.8 | 64.9 | 5.7 |
| 6 | 80.4 | 69.3 | 64.9 | 61.9 | 6.2 |
| 7 | 96.1 | 94.5 | 91.6 | 88.2 | 2.6 |
| 8 | 93.5 | 82.0 | 69.7 | 62.1 | 10.5 |
| 9 | 78.2 | 67.6 | 64.0 | 61.9 | 5.4 |
| 10 | 68.3 | 64.6 | 62.0 | 58.4 | 3.3 |
| 11 | 91.8 | 89.1 | 74.4 | 68.6 | 7.6 |
| 12 | 94.3 | 94.8 | 93.7 | 81.1 | 4.4 |

Table 4

Toe Temperatures Noted by Hour for Trials at 0° F for the Intermediate Cold Weather Sleeping Bag

| Subject No. | Toe Temperatures in Degrees F | | | | $\Delta T/hr$ |
|----------------|-------------------------------|----------|----------|----------|---------------|
| | 60 min. | 120 min. | 180 min. | 240 min. | |
| 1 | 90.6 | 79.3 | 70.8 | 62.8 | 9.3 |
| 2 | 90.8 | 87.5 | 84.2 | 79.6 | 3.7 |
| 3 | 67.6 | 61.3 | 58.2 | 55.7 | 4.0 |
| 4 | 70.8 | 65.7 | 61.2 | 56.8 | 4.7 |
| 5 | 67.6 | 62.9 | 57.8 | 57.4 | 3.4 |
| 6 | 86.9 | 80.0 | 74.0 | 69.7 | 5.7 |
| 7 | 75.4 | 64.3 | 60.0 | 56.4 | 6.3 |
| 8 | 80.9 | 79.1 | 72.8 | 72.2 | 2.9 |
| 9 | 74.8 | 66.4 | 60.5 | 57.1 | 5.9 |
| 10 | 78.1 | 70.1 | 67.0 | 65.5 | 4.2 |
| 11 | 76.6 | 66.6 | 61.4 | 57.3 | 6.4 |
| 12 | 90.7 | 85.5 | 80.0 | 68.2 | 7.5 |

Table 5

Toe Temperatures Noted by Hour for Trials at -30° F for the Extreme Cold Weather Sleeping Bag (intermediate bag inside of patrol bag and extreme cold weather mitten set on subjects' feet)

| Subject No. | Toe Temperatures in Degrees F | | | | $\Delta T/hr$ |
|-------------|-------------------------------|----------|----------|----------|---------------|
| | 60 min. | 120 min. | 180 min. | 240 min. | |
| 1 | 76.4 | 70.3 | 65.1 | 58.8 | 5.9 |
| 2 | 89.6 | 87.4 | 85.0 | 77.5 | 4.0 |
| 3 | 72.5 | 67.3 | 61.5 | 59.2 | 4.4 |
| 4 | 75.6 | 69.6 | 65.2 | 62.1 | 4.5 |
| 5 | 78.3 | 69.6 | 62.5 | 58.9 | 6.5 |
| 6 | 92.2 | 90.4 | 84.4 | 76.5 | 5.2 |
| 7 | 93.7 | 93.3 | 85.6 | 77.7 | 5.3 |
| 8 | 71.8 | 70.3 | 66.1 | 62.8 | 3.0 |
| 9 | 95.8 | 90.8 | 80.0 | 69.8 | 8.7 |
| 10 | 84.8 | 75.2 | 68.9 | 64.8 | 6.7 |
| 11 | 81.9 | 72.2 | 65.3 | 60.0 | 7.3 |
| 12 | 92.2 | 91.4 | 78.3 | 67.5 | 8.2 |

Group 1

The first four marines (Subjects 1 through 4) participated in a series of 4-hour trials to determine the lowest ambient air temperature at which each sleeping bag configuration (see Table 2) provided adequate thermal protection to afford 4 hours of comfortable rest or sleep.

Patrol Bag

Three 4-hour trials were necessary to determine the lowest air temperature for the patrol bag. Trials were conducted at +35° F, +25° F, and +30° F. All four subjects were able to maintain acceptable surface skin temperatures and core temperatures for all three trials. However, for the trial conducted at +25° F, one subject stated that he was slightly uncomfortable for the final 30 or 40 minutes. In addition, all four subjects expressed that they were colder from the knees downward at the +25° F temperature than they were during the trials conducted at warmer temperatures.

Intermediate Bag

Three trials were conducted to determine the lowest air temperature for the intermediate bag. Trials were conducted at +5° F, 0° F, and -5° F. Again, all four subjects were able to maintain acceptable surface skin temperatures and core temperatures for all three trials. For the trial conducted at +5° F, all four subjects stated that they felt exceptionally warm, and none experienced a skin temperature lower than 75.6° F. For trials conducted at 0° F, all the subjects stated that they rested comfortably or slept for the entire 4-hour exposure period. Two of these subjects stated that they knew that their feet were getting colder toward the end of the period but not to such a degree that they were uncomfortable and could not at least rest comfortably. For the trial conducted at -5° F, the subjects' toe temperatures were notably colder than those recorded during the previous trials. Three of the subjects stated that they were able to sleep or rest comfortably, but one stated that he awoke after about 2 hours

because of cold feet. He also stated that his feet were cold for the last 2 hours but stated that he did not feel uncomfortable.

Cold Weather Bag

Three trials were conducted by this group for the cold weather bag. The first trial conducted at an ambient air temperature of -30°F was one where the subjects wore extreme cold weather mitten sets on their feet for the duration of the trial. All four subjects maintained acceptable skin and core temperatures and stated that they slept or rested comfortably for the entire exposure period. Two subjects (Subjects 1 and 3, respectively) had toe temperatures slightly less than 60°F (58.8 and 59.2) at the end of the 4-hour period, but neither dropped below 60°F before 215 minutes of exposure. Subject 1 had stated previously that he awoke and was uncomfortable for the last 1-1/2 hours during a trial at -5°F in the intermediate bag because of cold feet (toe temperature of 57.8°F at 3-hour reading). He stated after this -30°F trial that his feet were starting to feel cold but that he was able to rest comfortably. Since he was only 1° from the toe temperature at which he previously stated he was uncomfortable, the experimenters decided that trials at lower chamber temperatures were not necessary and that -30°F would be the lowest temperature for trials conducted for the cold weather sleeping bag configuration.

A second trial was conducted at an ambient air temperature of -25°F . All subjects maintained acceptable skin and core temperatures and stated that they slept or rested comfortably for the entire exposure period. The purpose of the -25°F trial was to build a data base that could be used if the remaining subjects (Groups 2 and 3) could not pass the -30°F trial.

An additional trial was conducted at an ambient air temperature of -30°F , during which none of the subjects wore the extreme cold weather mitten set on their feet. This trial was requested by the project officer from Marine Corps Systems Command to determine if the modular sleeping bag could provide adequate thermal protection without the use of the mitten set. All four subjects were able to maintain acceptable skin and core temperatures, but three of these subjects stated that they were uncomfortable. Two subjects stated that they did not hurt but were uncomfortable for the last 90 minutes of the trial. The other stated that he was uncomfortable for approximately 20 minutes, then rewarmd and was comfortable for the remainder of the trial. The data recorded during this trial indicated that the toe temperatures for these three subjects fell below 60°F after 150 minutes and continued to fall for the remainder of the exposure period. Their ending toe temperatures were 53.3°F , 52.6°F , and 56.1°F . The remaining subject was comfortable and had an ending toe temperature of 78.4°F .

Based on the objective and subjective data collected during the trials conducted with this subject group, it was determined that the lowest ambient air temperatures at which the sleeping bag configurations provided adequate thermal protection was $+30^{\circ}\text{F}$ for the patrol bag, 0°F for the intermediate bag, and -30°F for the cold weather bag with the extreme cold weather mitten set. Consequently, these were the configurations and starting temperatures established for trials conducted by the second and third subject groups (Subjects 5 through 12).

Group 2

The second group of marines (Subjects 5 through 8) conducted trials for each sleeping bag configuration at the ambient air temperatures established by the first group. The results of these trials indicated that all four subjects maintained acceptable skin and core temperatures and slept or rested comfortably for the entire exposure period. In addition, these subjects conducted a trial in the cold weather sleeping bag with the extreme cold weather mitten set on

their feet at -25° F and a trial in the intermediate sleeping bag at +5° F. These trials were conducted to ensure that there were sufficient data available in case subjects from the final group could not pass trials at the lower temperatures established for the cold weather and intermediate sleeping bag configurations.

Group 3

The final group of marines (Subjects 9 through 12) participated in trials for each sleeping bag configuration at the ambient air temperatures that were established. The results of these trials show that all four subjects maintained acceptable skin and core temperatures and slept or rested comfortably for the entire exposure period. Since this group was able to successfully complete these trials, the Marine Corps project officer requested that we conduct an additional trial for the intermediate bag at 0° F. He wanted to repeat the trial with subjects wearing the extreme cold weather mitten set on their feet to determine if the mitten set would provide additional thermal protection for this sleeping configuration. The temperature data recorded during this trial were compared to the trial conducted at 0° F (in which the subjects did not wear the mitten set). The objective data shown in Tables 6 and 7 indicate that the subjects' toe temperatures were warmer when wearing the mitten set on their feet than when the mitten set was not worn. In addition, three of the four subjects stated that they felt much more comfortable when the mitten set was worn. (Temperatures listed in the 240-minute column in Tables 6 and 7 were not significantly different, $t = 1.62$, $p > .05$.)

Table 6

Toe Temperatures Noted by Hour for Trials at 0° F for Subjects Wearing Extreme Cold Weather Mittens (on subjects' feet) in the Intermediate Sleeping Bag

| Subject No. | Toe Temperatures in Degrees F | | | | |
|-------------|-------------------------------|---------|----------|----------|----------|
| | 0 min. | 60 min. | 120 min. | 180 min. | 240 min. |
| 9 | 83.8 | 87.1 | 76.0 | 69.0 | 64.8 |
| 10 | 80.0 | 75.3 | 72.2 | 69.1 | 67.7 |
| 11 | 79.1 | 71.9 | 66.5 | 61.5 | 60.7 |
| 12 | 85.4 | 93.2 | 91.8 | 84.5 | 79.6 |

Table 7

Toe Temperatures Noted by Hour for Trials at 0° F for Subjects Not Wearing Extreme Cold Weather Mittens in the Intermediate Sleeping Bag

| Subject No. | Toe Temperatures in Degrees F | | | | |
|-------------|-------------------------------|---------|----------|----------|----------|
| | 0 min. | 60 min. | 120 min. | 180 min. | 240 min. |
| 9 | 83.3 | 74.8 | 66.4 | 60.5 | 57.1 |
| 10 | 88.0 | 78.1 | 70.1 | 67.0 | 65.5 |
| 11 | 79.1 | 76.6 | 66.6 | 61.4 | 57.3 |
| 12 | 93.9 | 90.7 | 85.5 | 80.0 | 68.2 |

Subjective Evaluation

The subjects commented about specific features or characteristics of the modular sleeping bag during post-trial debriefing sessions. Subjects indicated that cold air did not seep down through the opening in the hoods or through zippers. However, two subjects who had used one particular modular sleeping bag stated that they could feel cold air seeping into the foot box of the intermediate sleeping bag when it was used by itself. An examination of this particular bag revealed that there was an additional stitched seam in its lower section just below the end of the zipper closure as illustrated in Figure 1. None of the other intermediate bags had this additional seam. This may explain why this negative comment was made by subjects using this particular bag. This may be a quality control problem and is worthy of comment.

Most of the subjects stated that the draft collar sewn inside the intermediate sleeping bag (the collar that seals around neck and shoulders illustrated in Figure 2) is a very positive feature. These same subjects noted that the draft collar seals better and is more effective when the modular sleeping bag is used in the extreme cold configuration where both hoods can be adjusted. It was the consensus of the subjects that the extreme cold weather bag felt more comfortable at -30° F than did the intermediate bag at 0° F. The subjects also stated that they felt the intermediate bag at 0° F was the worst sleeping bag configuration assessed. Many subjects felt that the modular sleeping bag kept the upper body extremely warm, regardless of configuration.

All the subjects stated that there was an adequate amount of room within the bag and that the hoods fit well and could be drawn tightly closed. No comments were made about air leaking through the zipper closures or about the zippers binding on material or working improperly. There were no occurrences of the snaps that attach the two bags together becoming unsnapped.

Five of the subjects who participated in this assessment also participated in the evaluations conducted during January through March 94. Four participated in the field evaluations and one in the controlled chamber assessment. The comments made by these subjects indicate that the modular sleeping bag had been vastly improved since they had last used it. They noted that the latest improved version had more room and that the hood fit much better and could be sealed tightly about the head and face. They also noted that the storm flap for the zipper was improved, that cold air was not felt through the zipper closures and the zippers operated much more smoothly. In addition, they stated that the snaps that hold the two bags together did not become unsnapped when using the bag as did the previous model, but it was somewhat more difficult to fasten the snaps together.



Figure 1. Photograph illustrating the additional seam identified in the lower section of this particular intermediate sleeping bag. (The middle arrow shows this seam.)



Figure 2. Photograph illustrating the addition of a draft collar sewn inside the intermediate sleeping bag.

CONCLUSIONS

1. The patrol bag with the clothing ensemble described provided adequate thermal protection to afford the subjects in this study 4 hours of comfortable rest or sleep at an ambient air temperature of +30° F. No subject reported discomfort from being cold.
2. The intermediate sleeping bag with the clothing ensemble described provided adequate thermal protection to afford the subjects in this study 4 hours of comfortable rest or sleep at an ambient air temperature of 0° F. No subject reported discomfort from being cold.
3. The extreme cold weather sleeping bag with the clothing ensemble described and the extreme cold weather mitten set on the users' feet provided adequate thermal protection to afford the subjects in this study 4 hours of comfortable rest or sleep at an ambient air temperature of -30° F. No subject reported discomfort from being cold.

RECOMMENDATIONS

1. Based on the results of this study, it is recommended that the improved version of the modular sleeping bag be considered for future use by the USMC.
2. Recommend that field trials in operational environments be conducted to further determine user acceptance of the improved modular sleeping bag.
3. Determine, if possible, the manufacturing defect in the modular sleeping bag, which was reported , that caused cold air to seep into the foot box section of the intermediate bag.

REFERENCES

- Gordon, C.C., Churchill, T., Clauser, C.E., Bradtmiller, B., McConville, J.T., Tebbetts, I., & Walker, R.A. (1989). 1988 anthropometric survey of U.S. Army personnel: Summary statistics (Technical Report No. NATICK/TR-89/027). Natick, MA: U.S. Army Natick Research, Development, and Engineering Center.
- vanDilla, M. A., (1949). Laboratory and field studies. In L.A. Newburgh (Ed.), Physiology of heat regulation and the science of clothing (Chapter 11). Philadelphia, PA: W. B. Saunders.

APPENDIX A
VOLUNTEER CONSENT AFFIDAVIT

VOLUNTEER CONSENT AFFIDAVIT

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25; the proponent agency is DTIC

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087.

Principle Purpose: To document voluntary participation in the Clinical Investigation and Research Program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study, implementation of medical programs, adjudication of claims, and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A(1) - VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, _____, SSN _____, having full capacity to consent and having attained my _____ birthday, do hereby volunteer/give consent as legal representative for _____ to participate in Assessment to Determine Thermal Protective Capabilities of the USMC Modular Sleeping Bag (MSB) (Research study)

under the direction of Mr. Charles A Hickey

conducted at Aberdeen Proving Ground, MD

(Name of Institution)

The implications of my voluntary participation/consent as legal representative; duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

Mr. Charles A. Hickey (410) 278-5920

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury, I may contact

Chief, Patient Administration Branch

at Kirk Army Health Clinic, Aberdeen Proving Ground, MD 21005, (410) 278-2086

(Name, Address and Phone Number of Hospital (Includes Area Code))

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefits; however, if the person I represent may be required (military volunteer) or requested (civilian volunteer) to undergo certain examination it, in the opinion of the attending physician, such examinations are necessary for my/the person I represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

PART A (2) - ASSENT VOLUNTEER AFFIDAVIT (MINOR CHILD)

I, _____, SSN _____, having full capacity to consent and having attained my _____ birthday, do hereby volunteer for _____ to participate in _____

(Research Study)

under the direction of _____

conducted at _____

(Name of Institution)

(Continue on Reverse)

ASSESSMENT TO DETERMINE THERMAL PROTECTIVE CAPABILITIES OF THE
USMC MODULAR SLEEPING BAG (MSB)

PART B

You were presented a pretest briefing which verbally explained your involvement in the assessment of the thermal protective capability of the selected MSB prototype. Afterwards, you were given the opportunity to ask questions relative to your participation in the conduct of the test, and these questions were answered to your satisfaction before you volunteered to participate.

To reiterate, these tests will be conducted in a carefully controlled cold chamber to determine if the individual components and the combined components will provide you protection from the cold in temperatures ranging from +40° F to -45° F. You will participate in a four hour test in the cold chamber for each of the configurations, patrol bag, intermediate cold weather bag, the two bags mated to form the extreme cold weather bag, and extreme cold weather bag plus additional cold weather components. Subsequent tests may be required to determine the adequate thermal protection by raising or lowering the temperature for each configuration. No tests will be conducted at temperatures less than -45° F. No more than one four hour test scenario will be conducted in a given day.

It is necessary to monitor your skin and body core temperatures for two reasons: (1) your personal safety; and (2) to collect data relative to your performance in the sleeping ensemble. You will be instrumented before dressing each day with four temperature sensors connected to read-out instrumentation located outside the chamber. These sensors will be placed as follows: rectum; to measure inside body temperature; fingertip; large toe; and middle of back to measure skin temperatures. Observers outside the chamber will be monitoring these temperatures continually and recording all temperatures every one minute. You will be removed from any individual test at any time your rectal temperature goes down to 95.0° F. or any skin temperature goes down to 50° F. At these temperatures you may be uncomfortable, but at no risk whatever of cold injury.

Since you are a volunteer participant, Army Regulations (AR40-38 and AR70-25) require that your medical records be reviewed prior to your participation in a study. Since you are being asked to participate in a study where you will be exposed to low ambient air temperatures in an environmental chamber, your records will be medically screened by US Naval medical officers. This is to assure that you have not had a history of cold intolerance or cold injury, alcoholism, or circulatory disorder, and to assure that you are not or have not recently used medications which may interfere with body temperature regulation or shivering.

You will receive no direct benefits from your participation in this study other than the knowledge and experience you may gain. However, the results of these tests will help the USMC in the selection of an efficient modular sleeping bag system.

All data and medical information obtained about you as an individual will be considered privileged and held in confidence. Complete confidentiality can not be promised because information bearing on your health may be required to be reported to appropriate medical or command authorities.

The results of these tests will be confidential, that is, your identities will not be associated with published tests results. You have the right of access to any of the data collected on you. Any questions about this data access should be addressed to the test director, Mr. Charles A. Hickey.

APPENDIX B

PHOTOGRAPHS OF MODULAR SLEEPING BAG CONFIGURATIONS

PHOTOGRAPHS OF MODULAR SLEEPING BAG CONFIGURATIONS

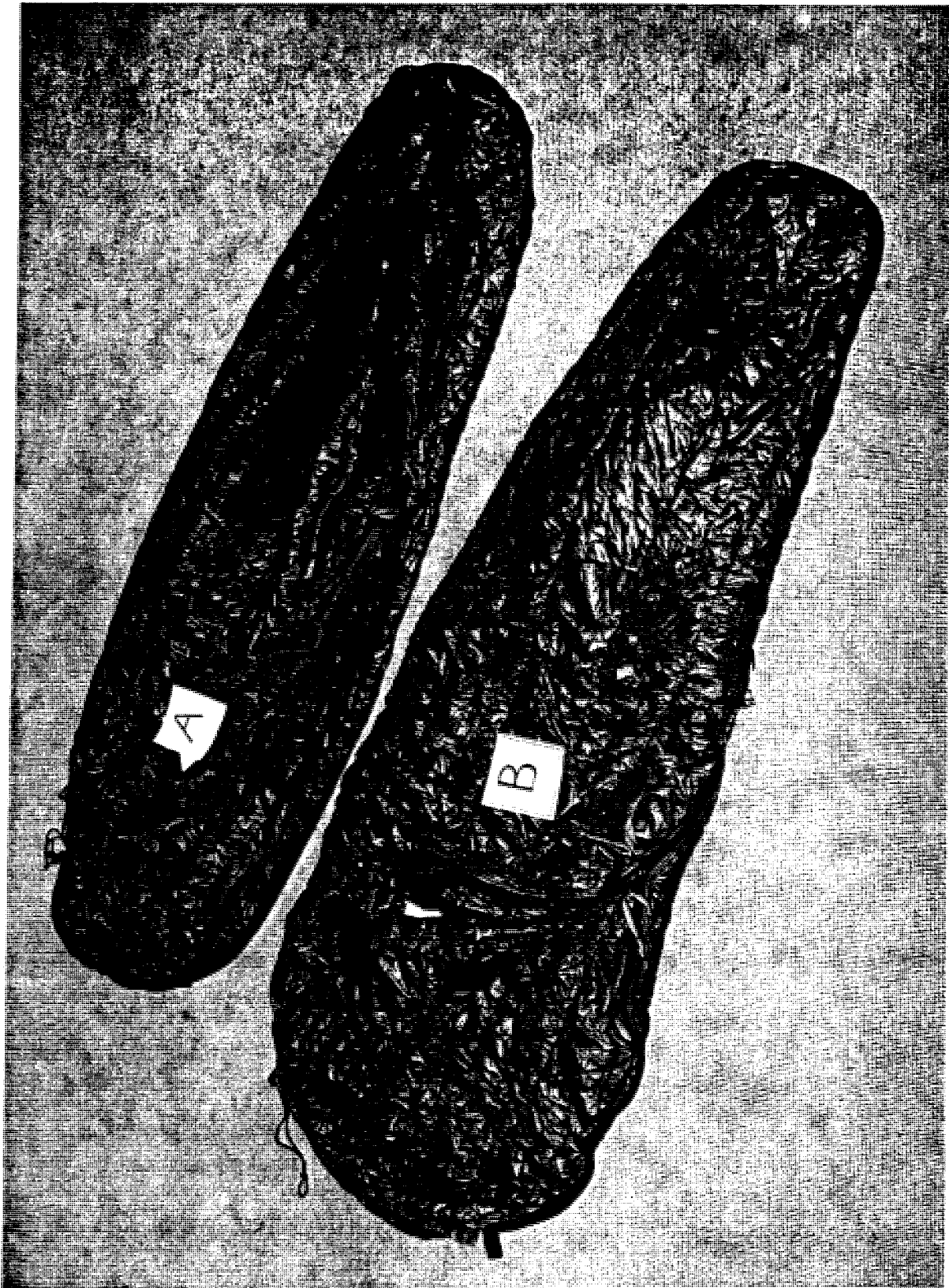


Figure B-1. Modular sleeping bags: A - intermediate; B - patrol.



Figure B-2. Modular sleeping bag: C - extreme cold weather.

APPENDIX C
TIME VERSUS TEMPERATURE GRAPHS

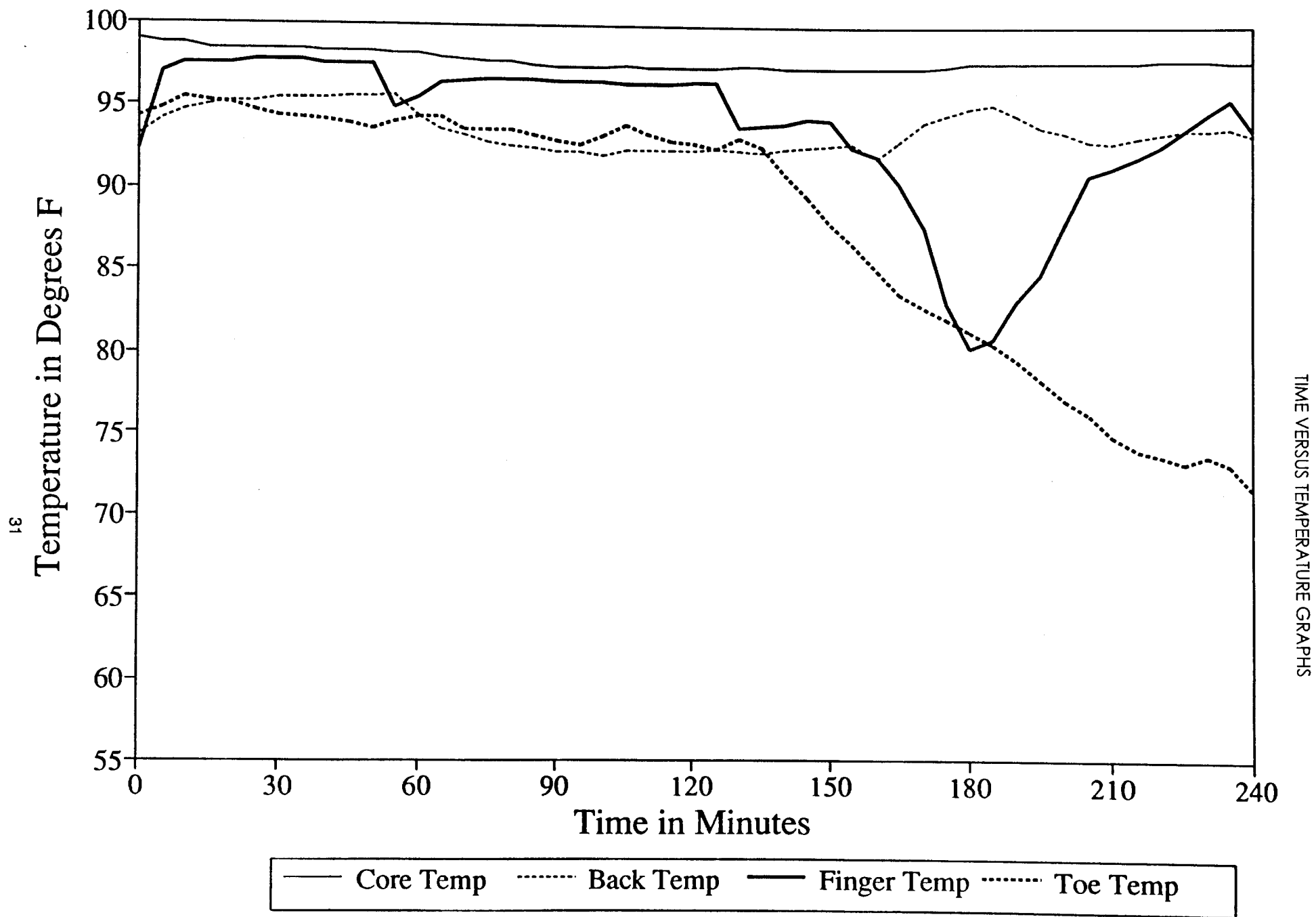


Figure C-1. Subject 1 in patrol bag at +30 degrees F.

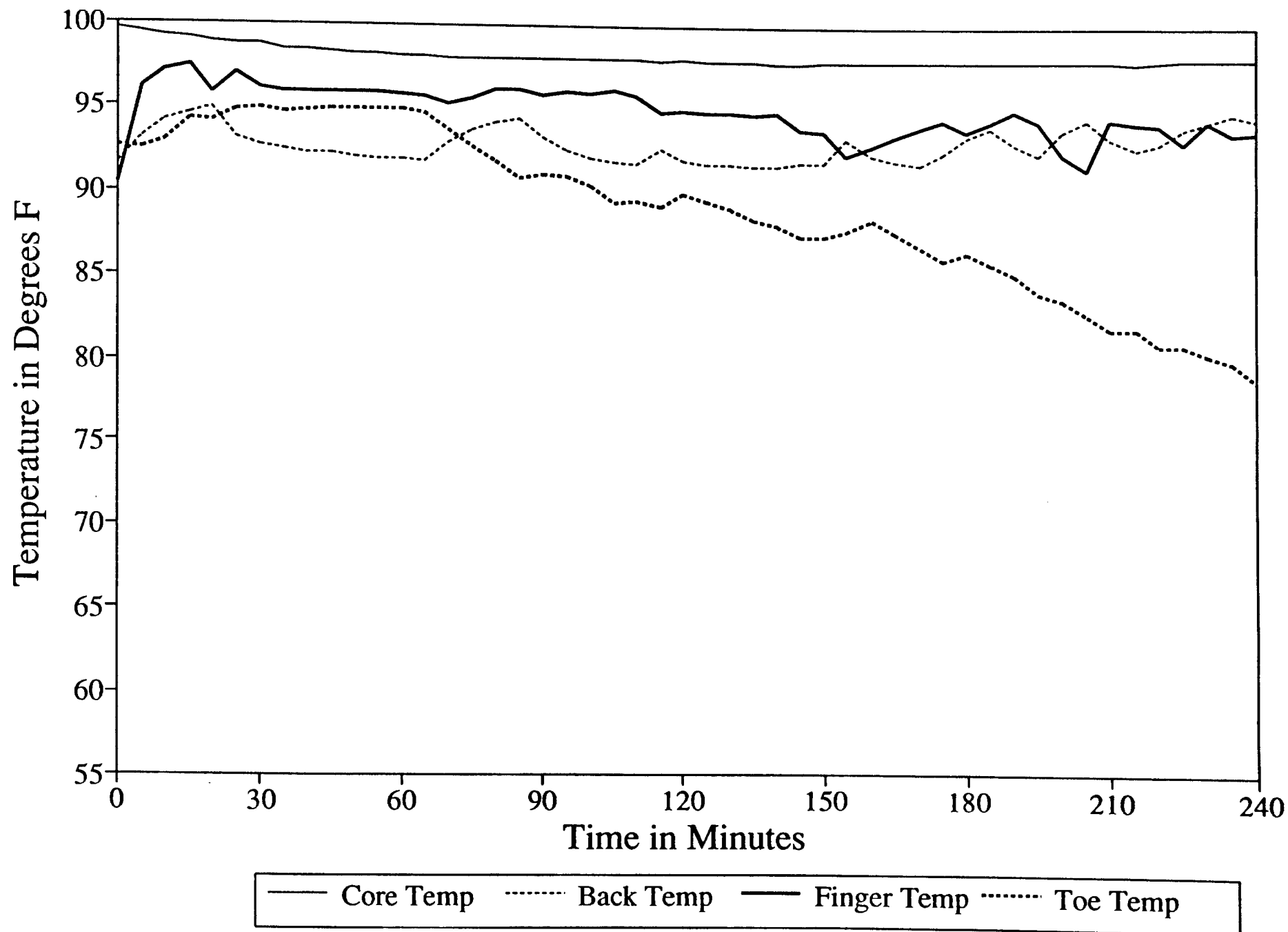


Figure C-2. Subject 2 in patrol bag at +30 degrees F.

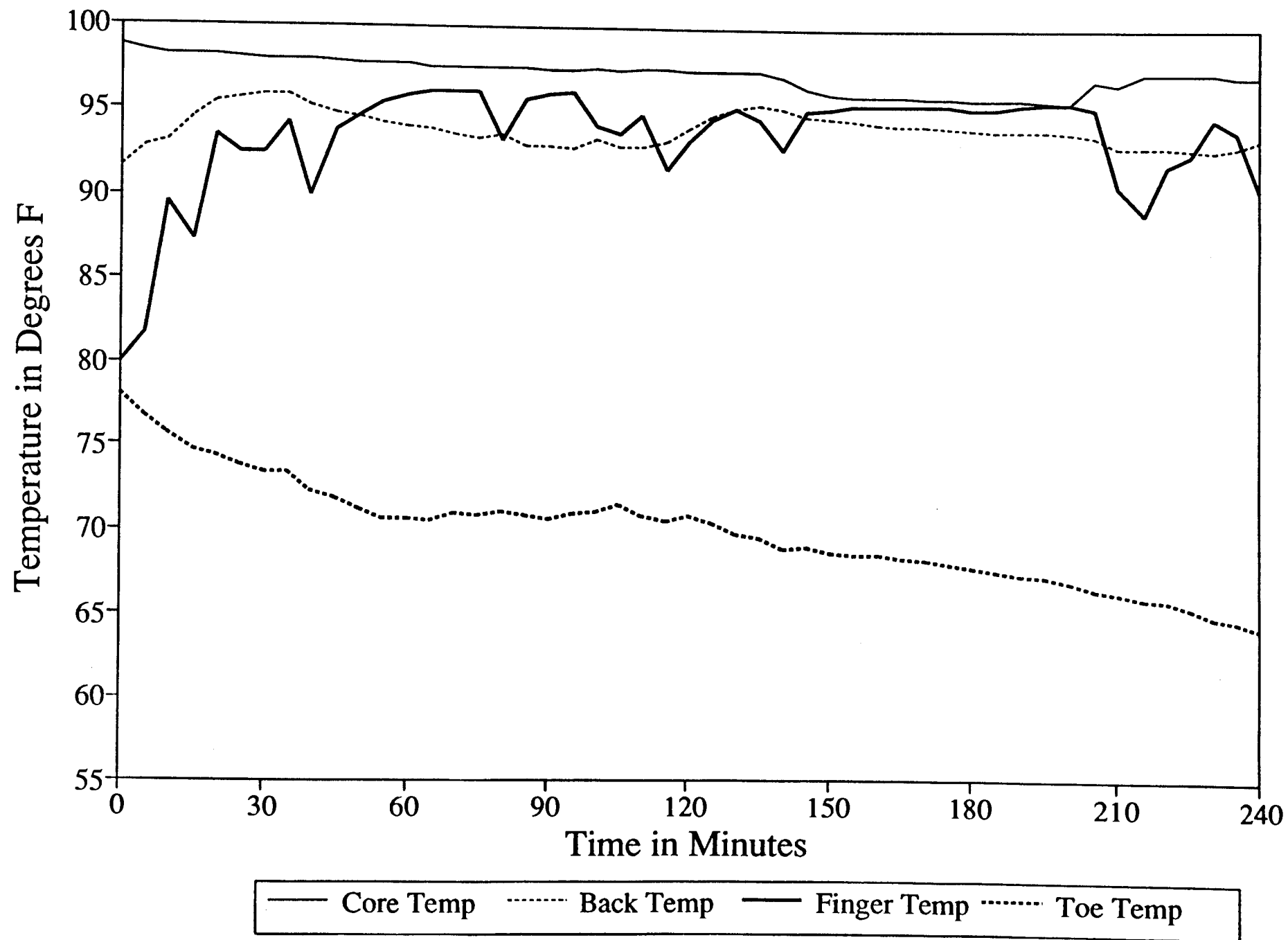


Figure C-3. Subject 3 in patrol bag at +30 degrees F.

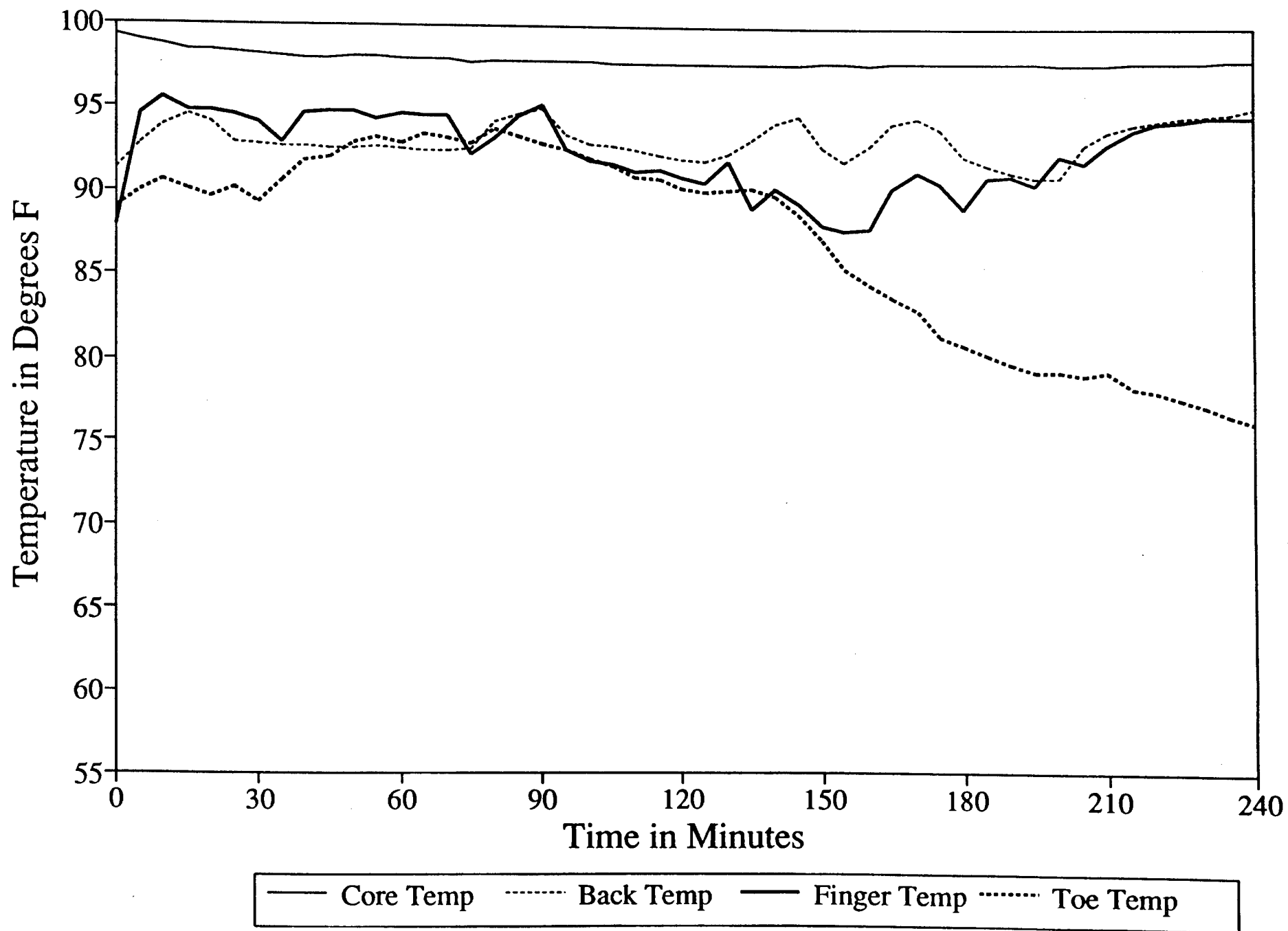


Figure C-4. Subject 4 in patrol bag at +30 degrees F.

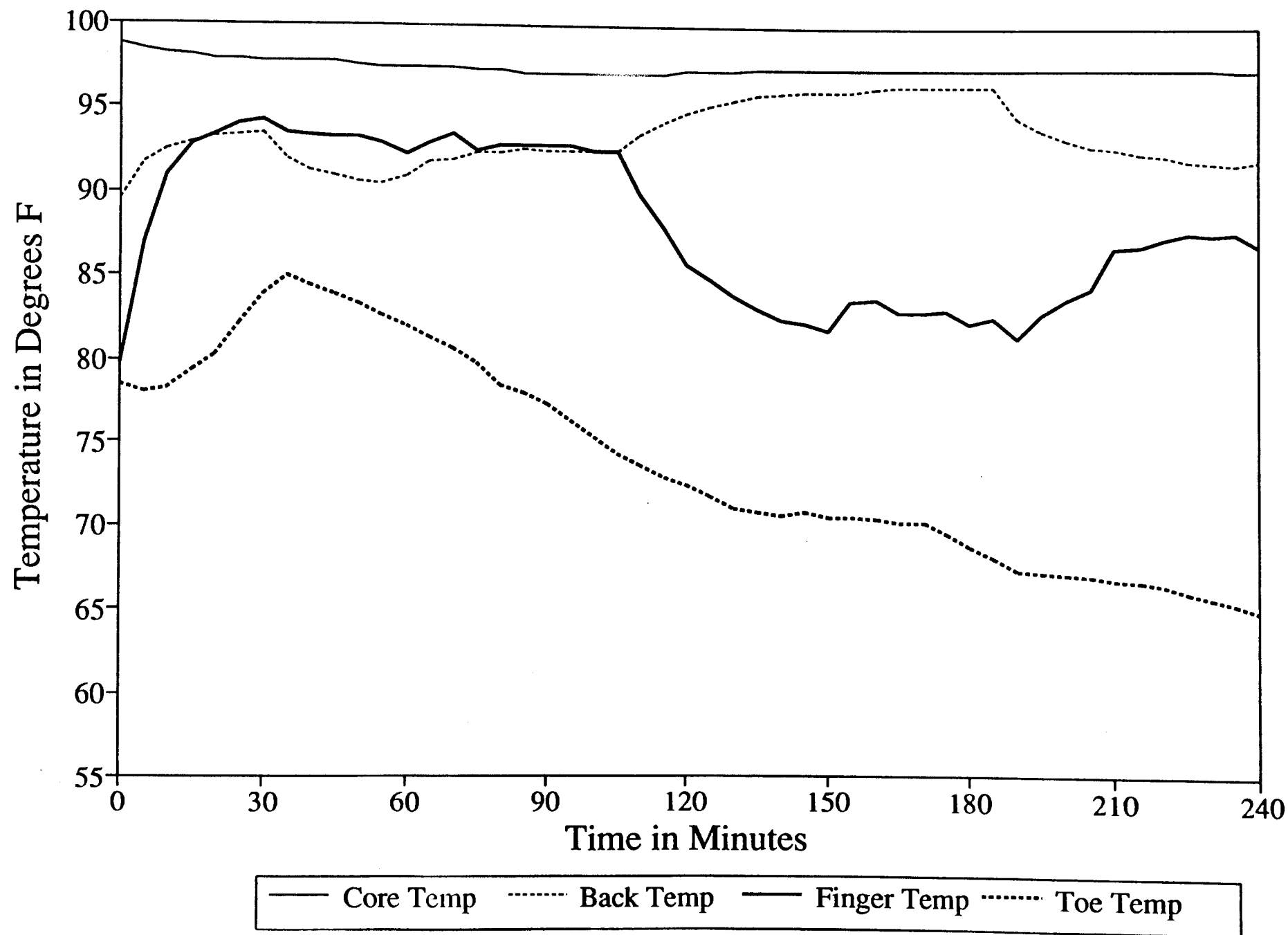


Figure C-5. Subject 5 in patrol bag at +30 degrees F.

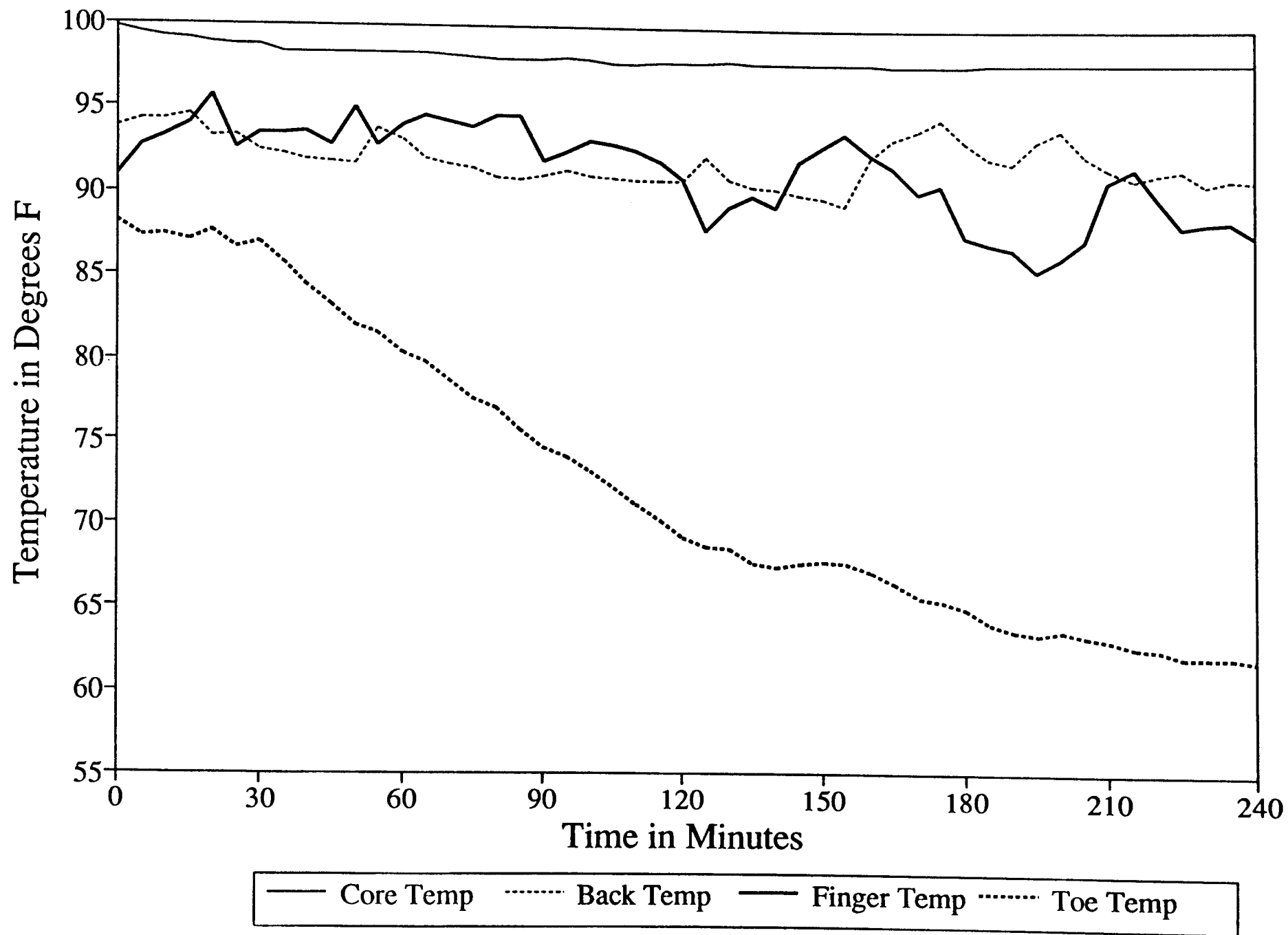


Figure C-6. Subject 6 in patrol bag at +30 degrees F.

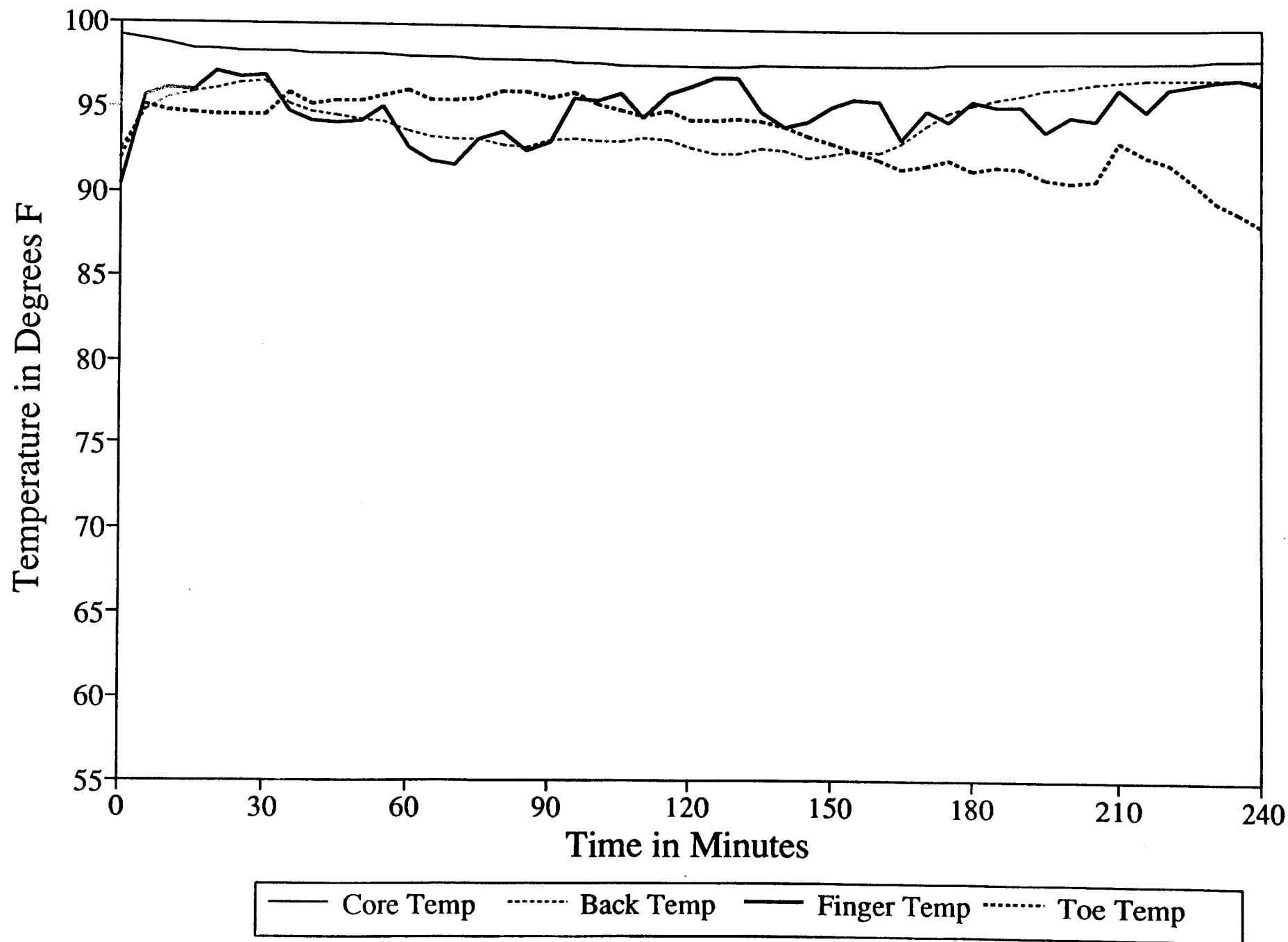


Figure C-7. Subject 7 in patrol bag at +30 degrees F.

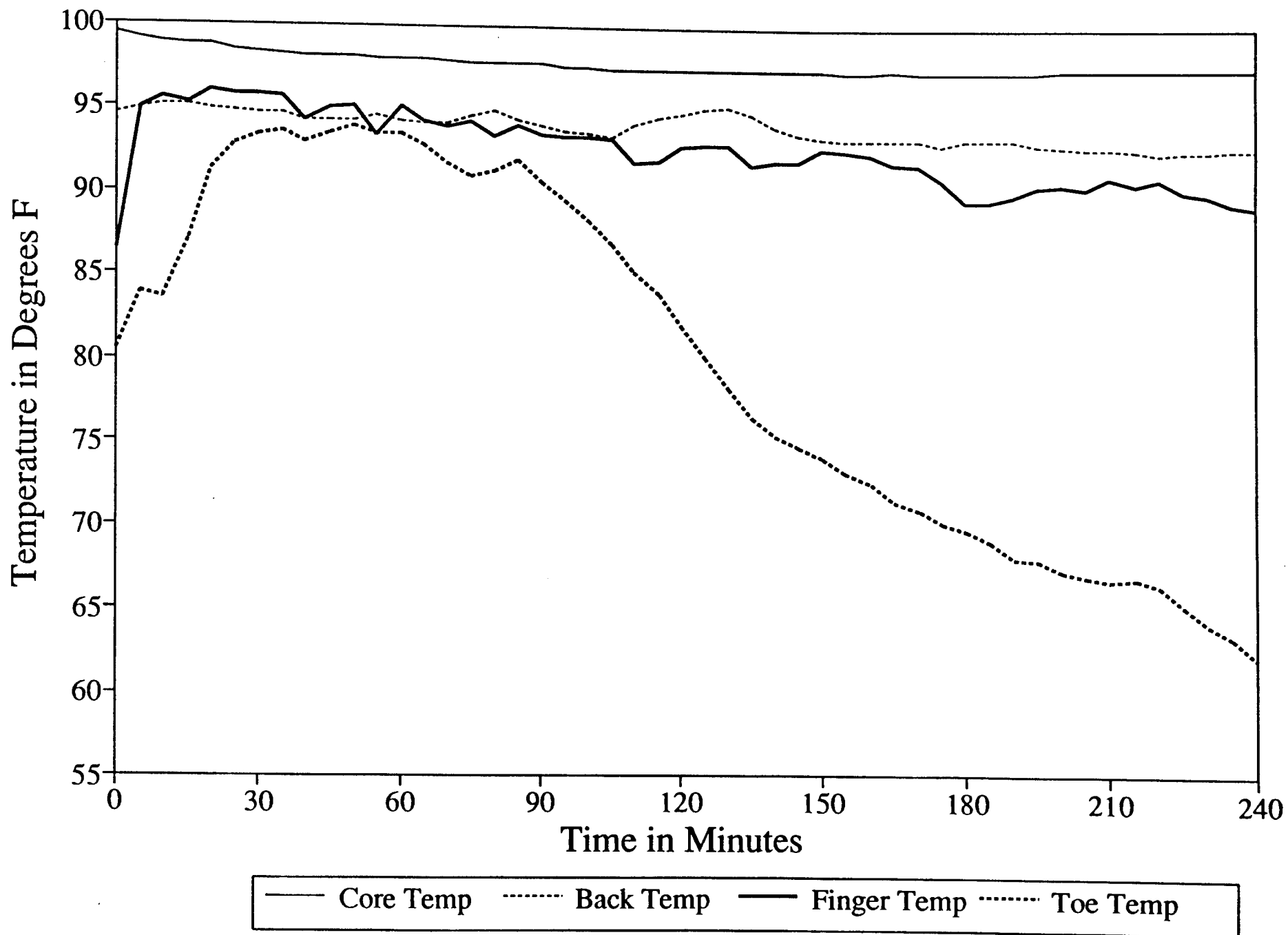


Figure C-8. Subject 8 in patrol bag at +30 degrees F.

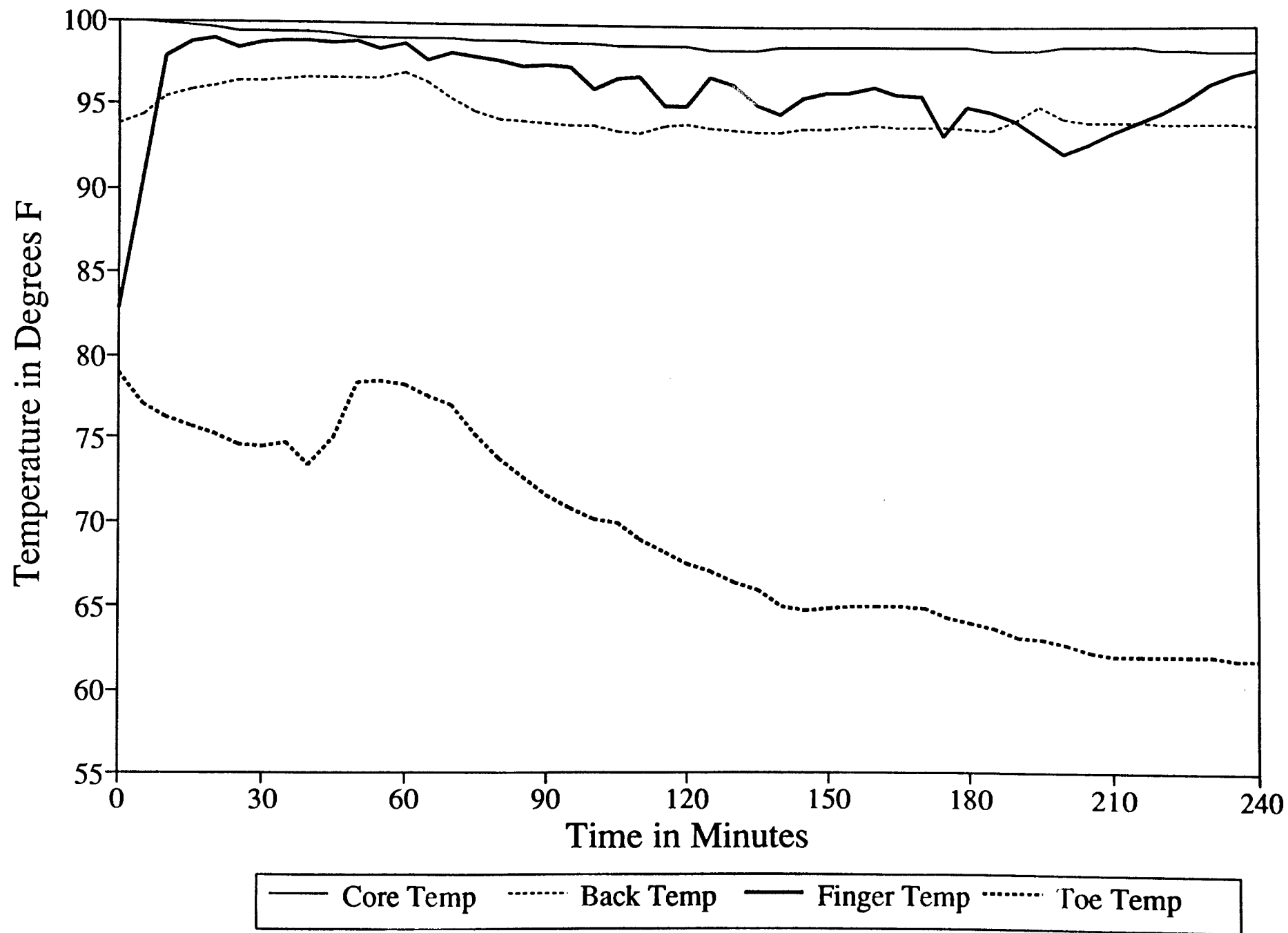


Figure C-9. Subject 9 in patrol bag at +30 degrees F.

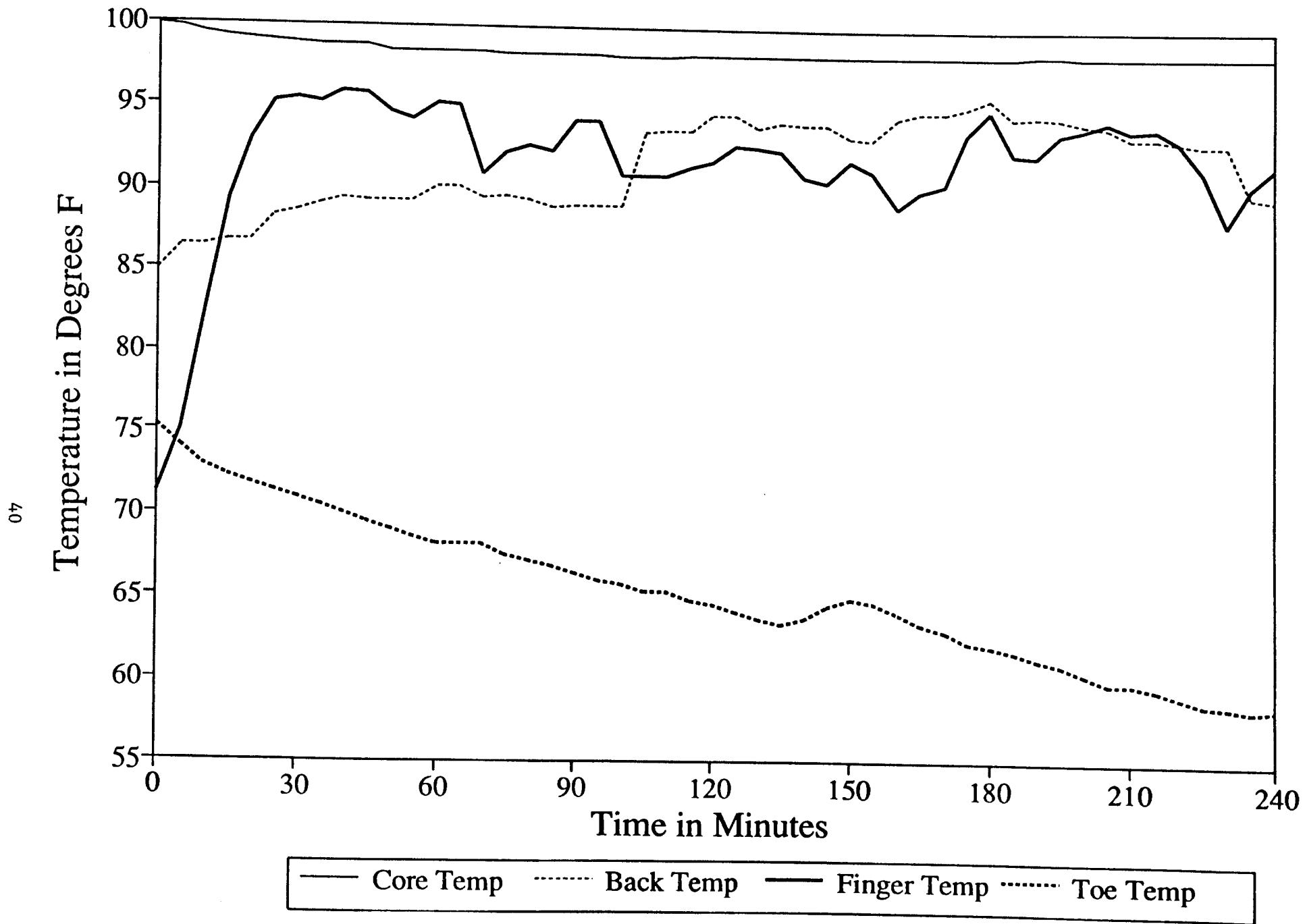


Figure C-10. Subject 10 in patrol bag at +30 degrees F.

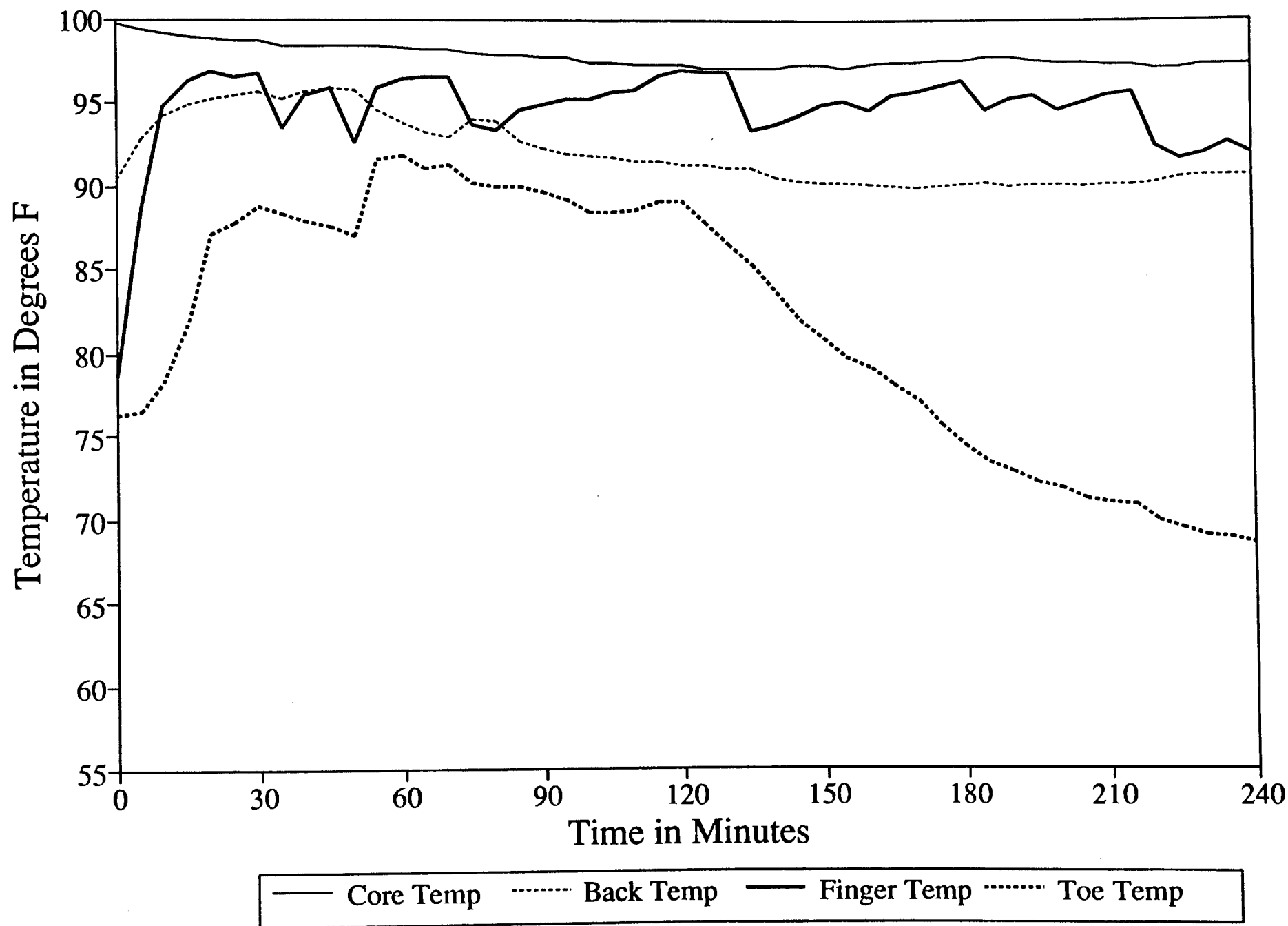


Figure C-11. Subject 11 in patrol bag at +30 degrees F.

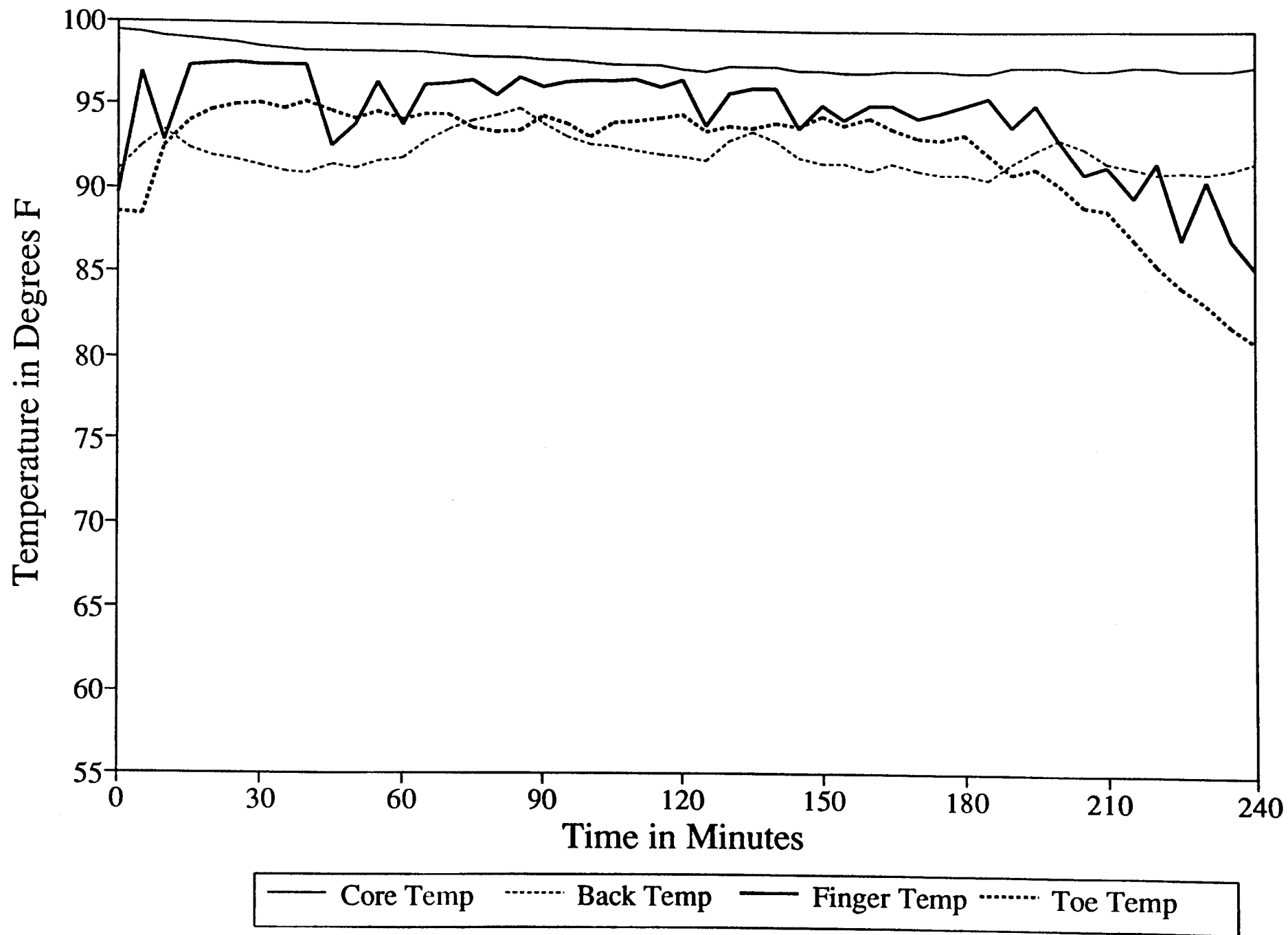


Figure C-12. Subject 12 in patrol bag at +30 degrees F.

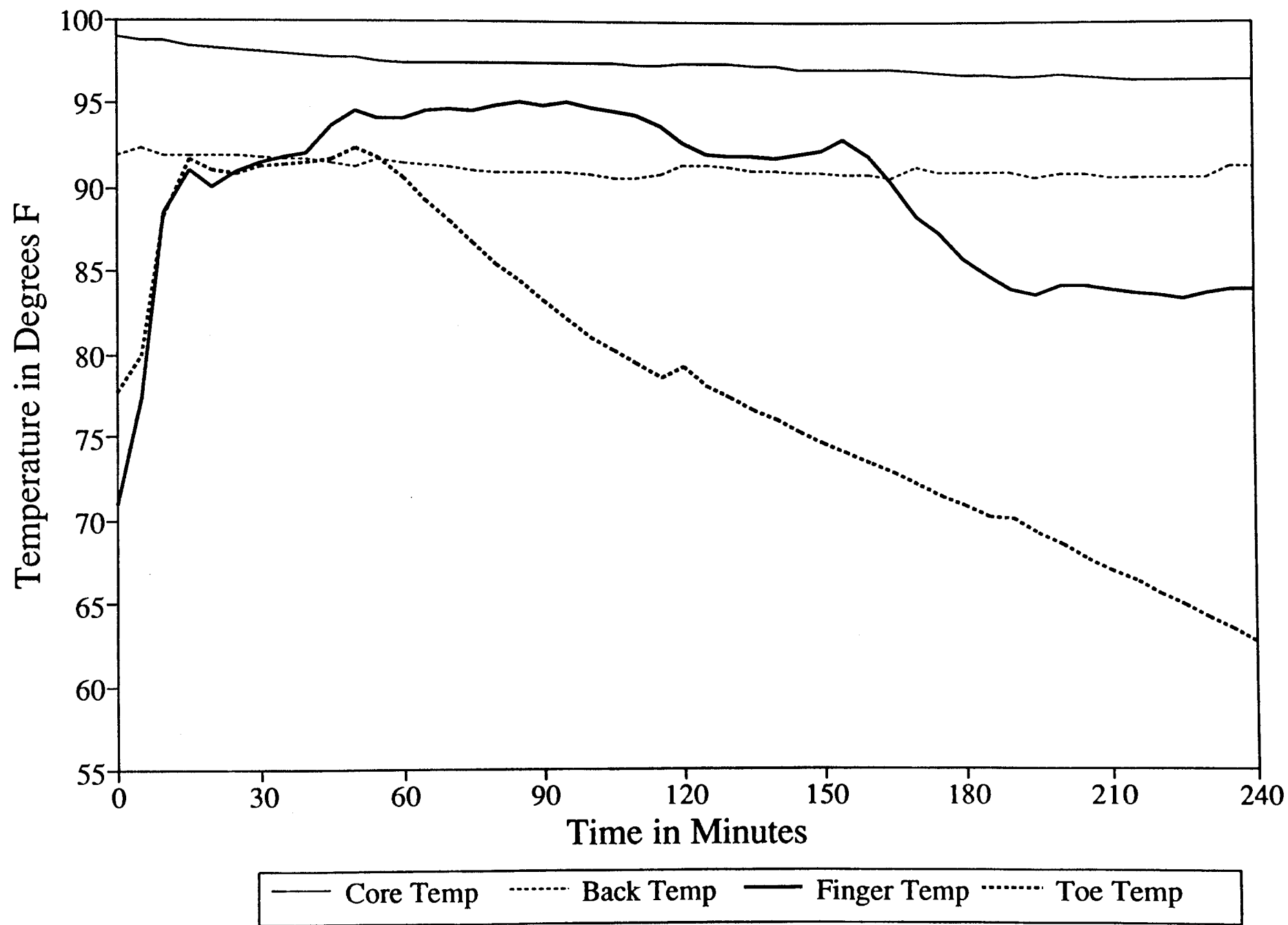


Figure C-13. Subject 1 in intermediate bag at 0 degrees F.

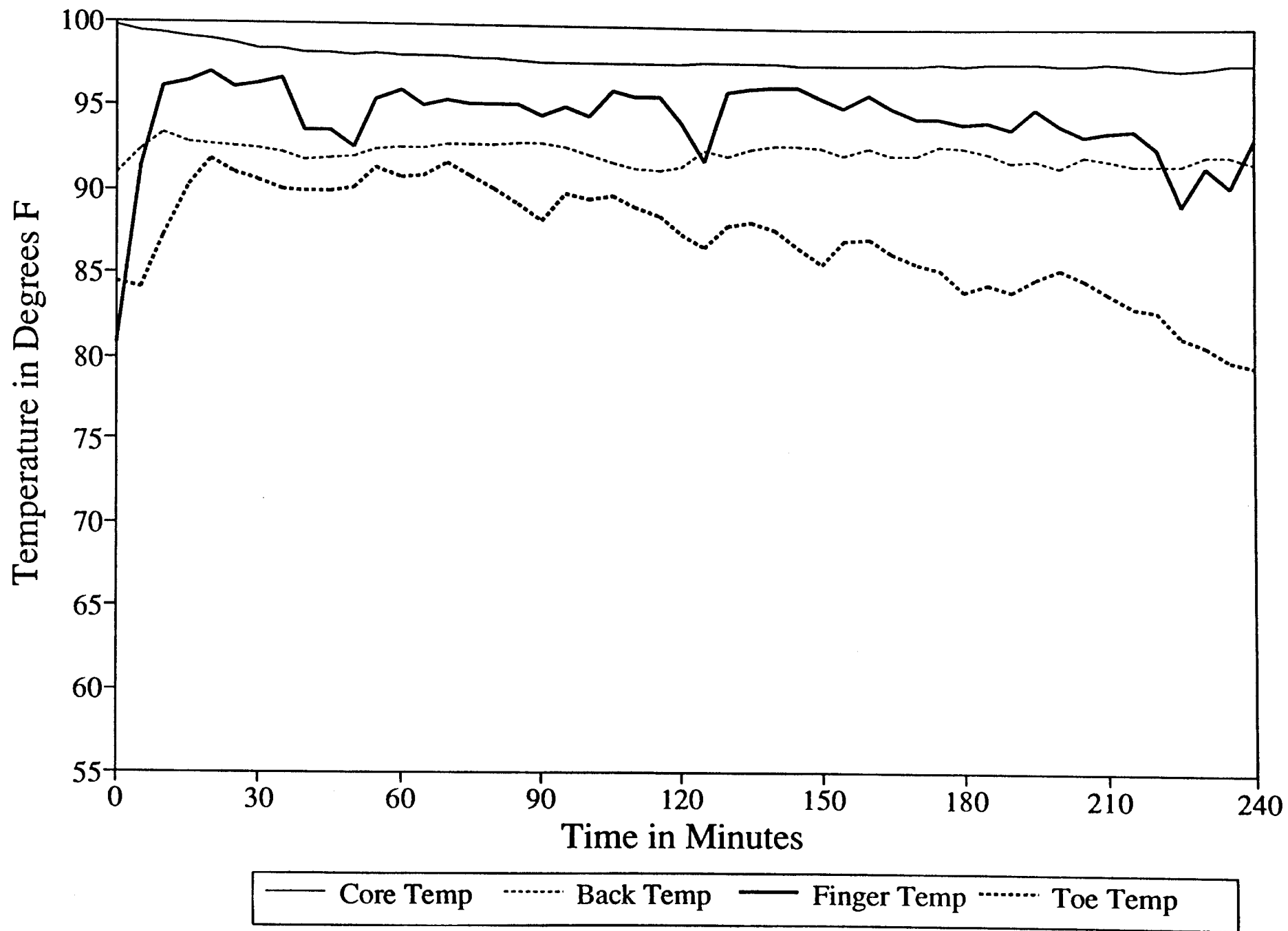


Figure C-14. Subject 2 in intermediate bag at 0 degrees F.

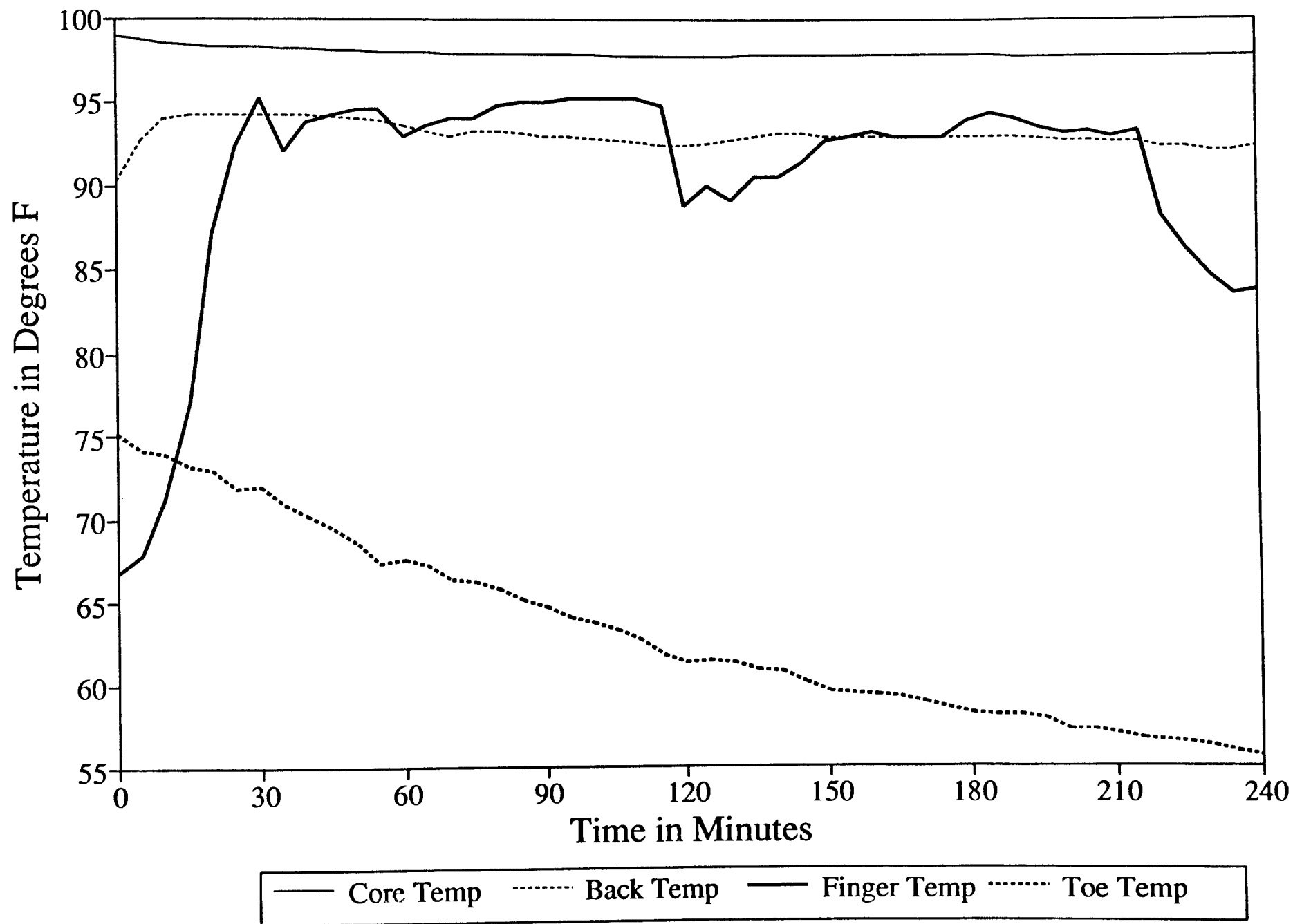


Figure C-15. Subject 3 in intermediate bag at 0 degrees F.

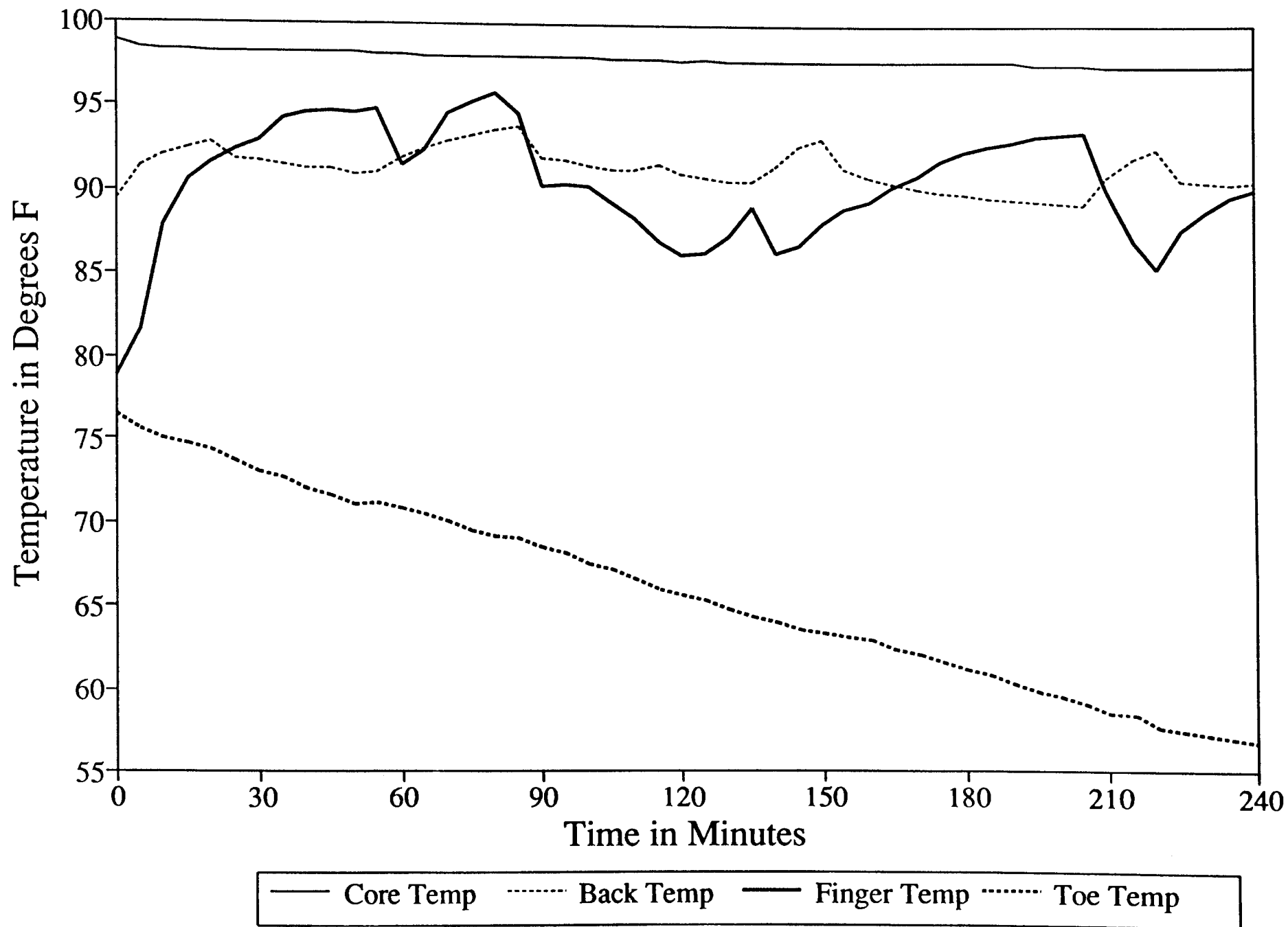


Figure C-16. Subject 4 in intermediate bag at 0 degrees F.

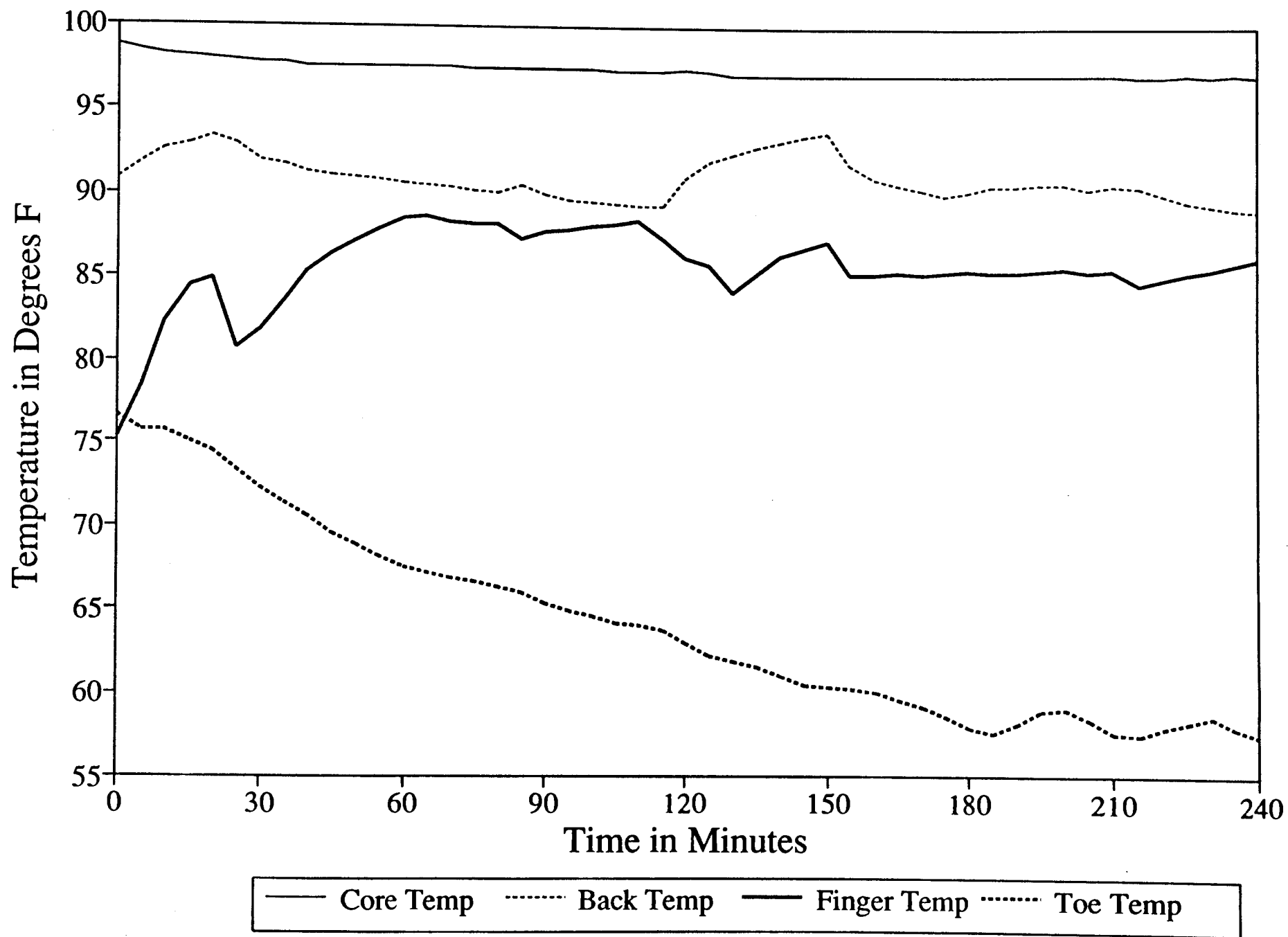


Figure C-17. Subject 5 in intermediate bag at 0 degrees F.

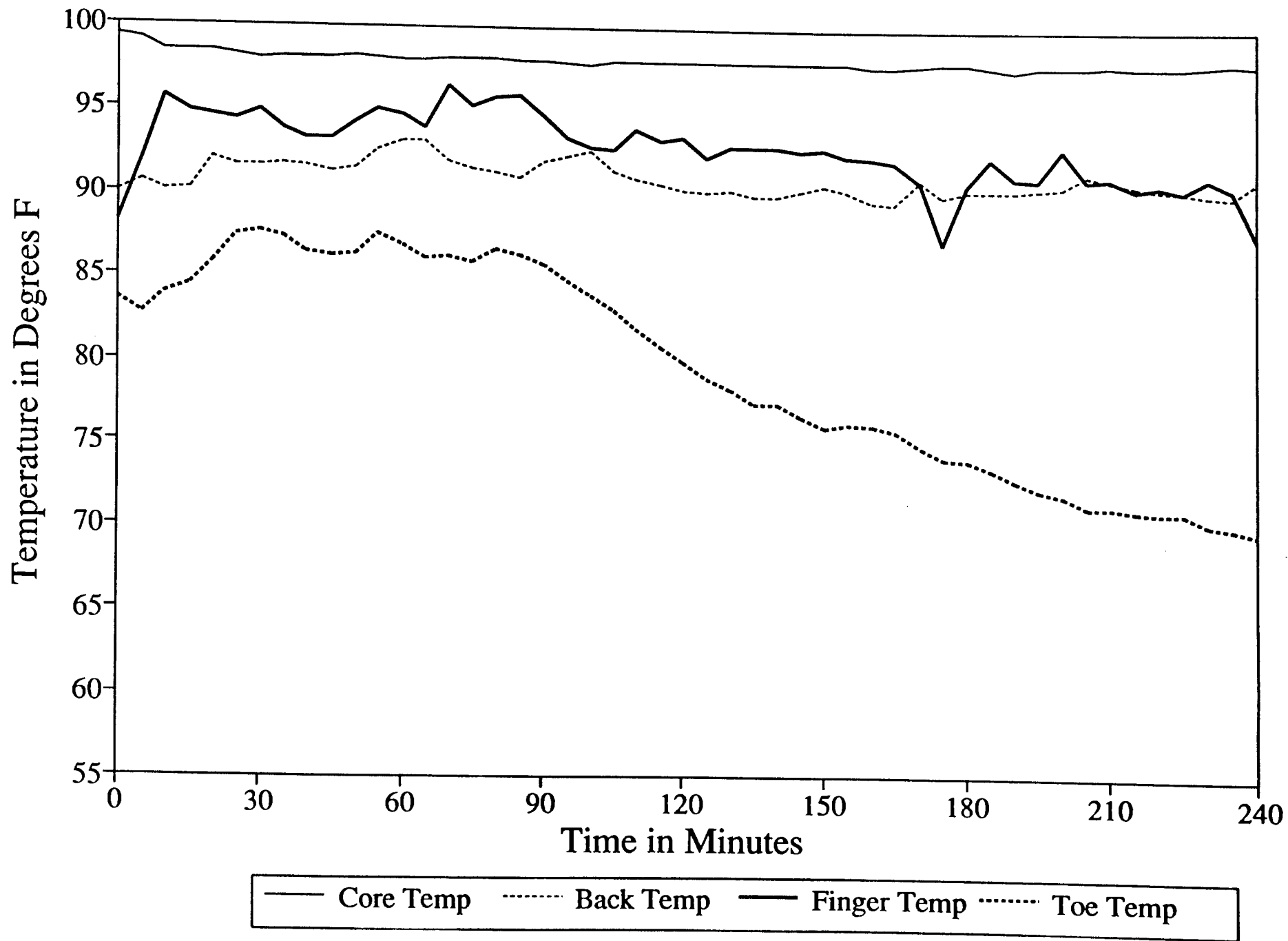


Figure C-18. Subject 6 in intermediate bag at 0 degrees F.

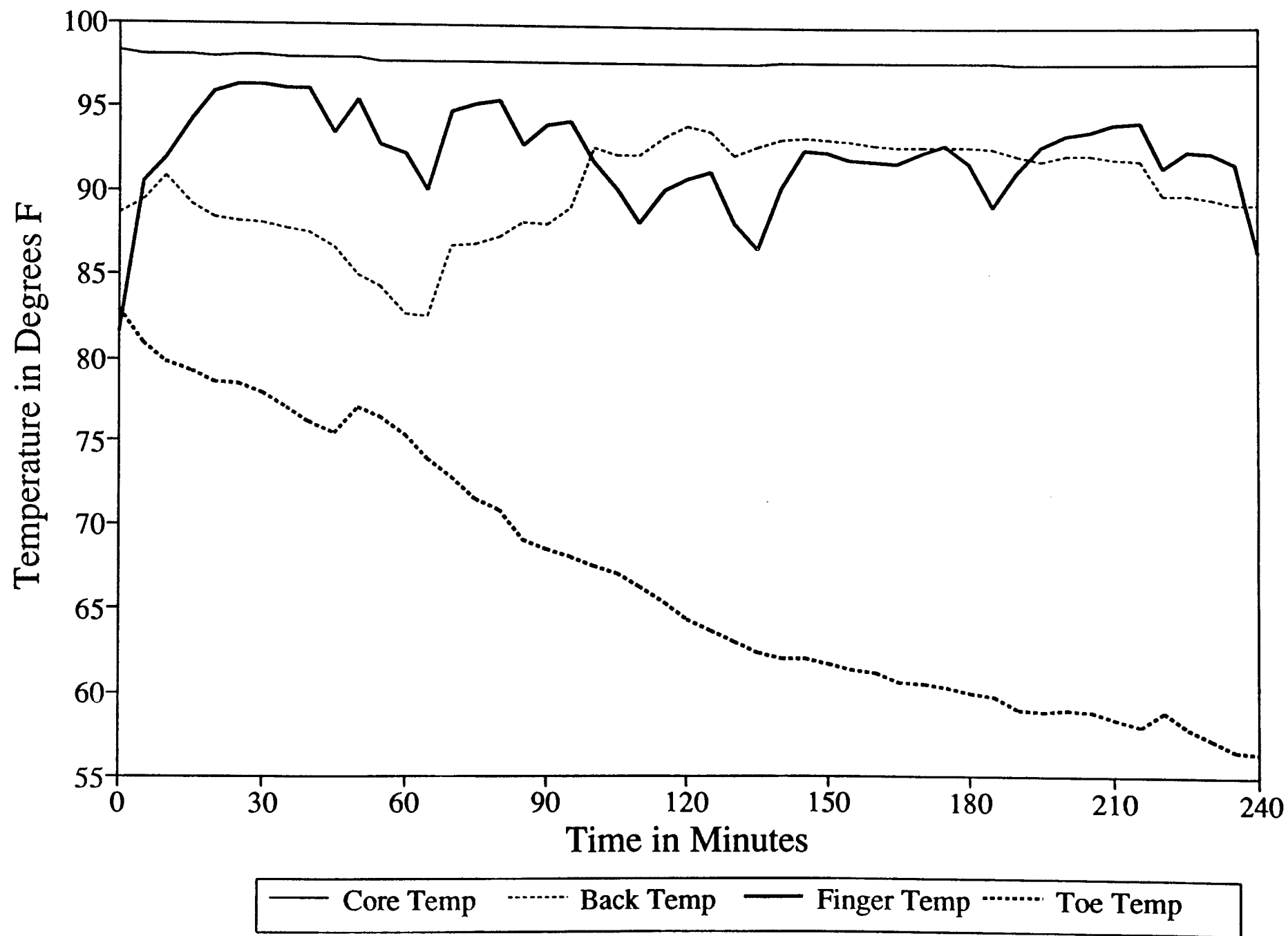


Figure C-19. Subject 7 in intermediate bag at 0 degrees F.

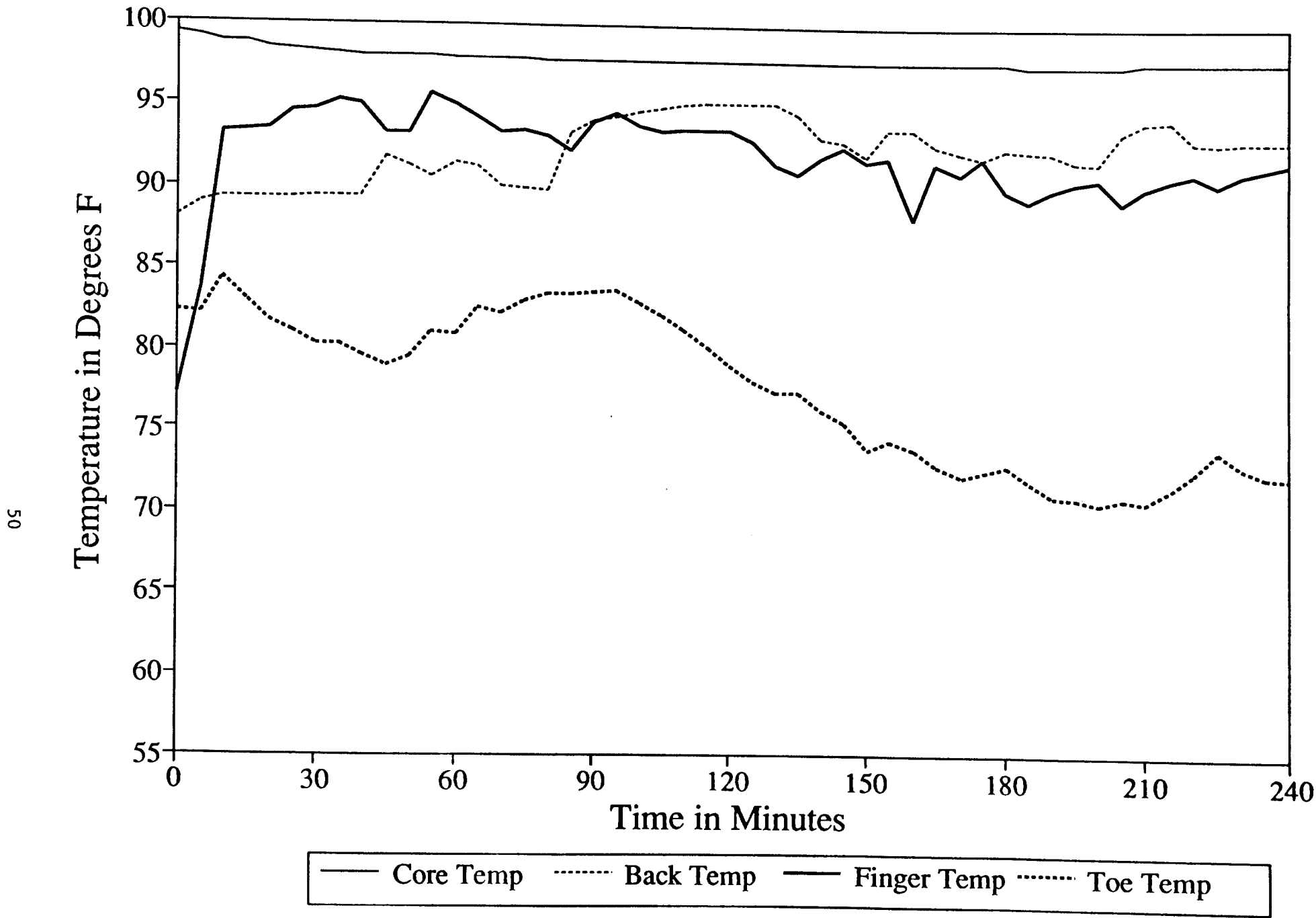


Figure C-20. Subject 8 in intermediate bag at 0 degrees F.

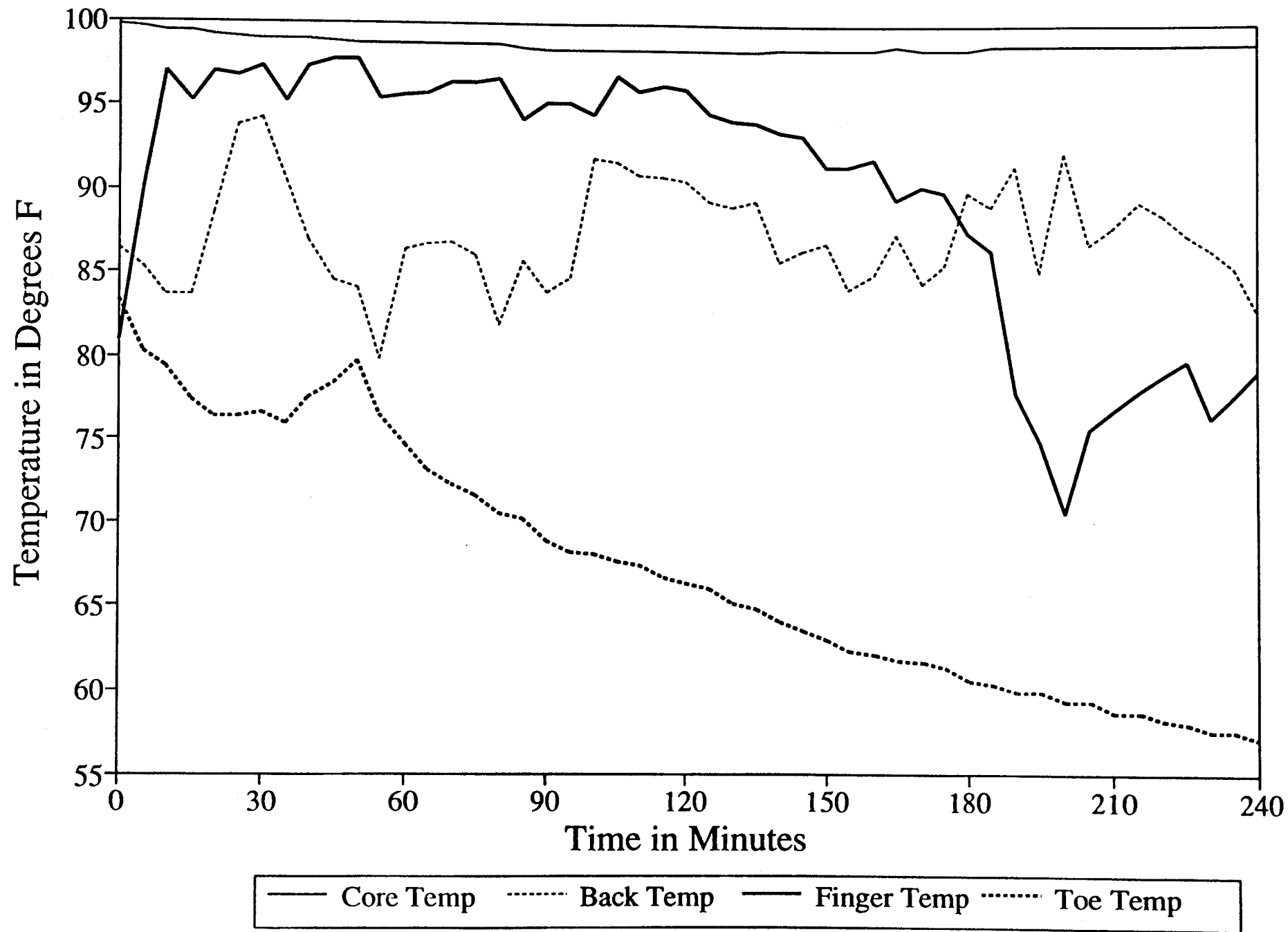


Figure C-21. Subject 9 in intermediate bag at 0 degrees F.

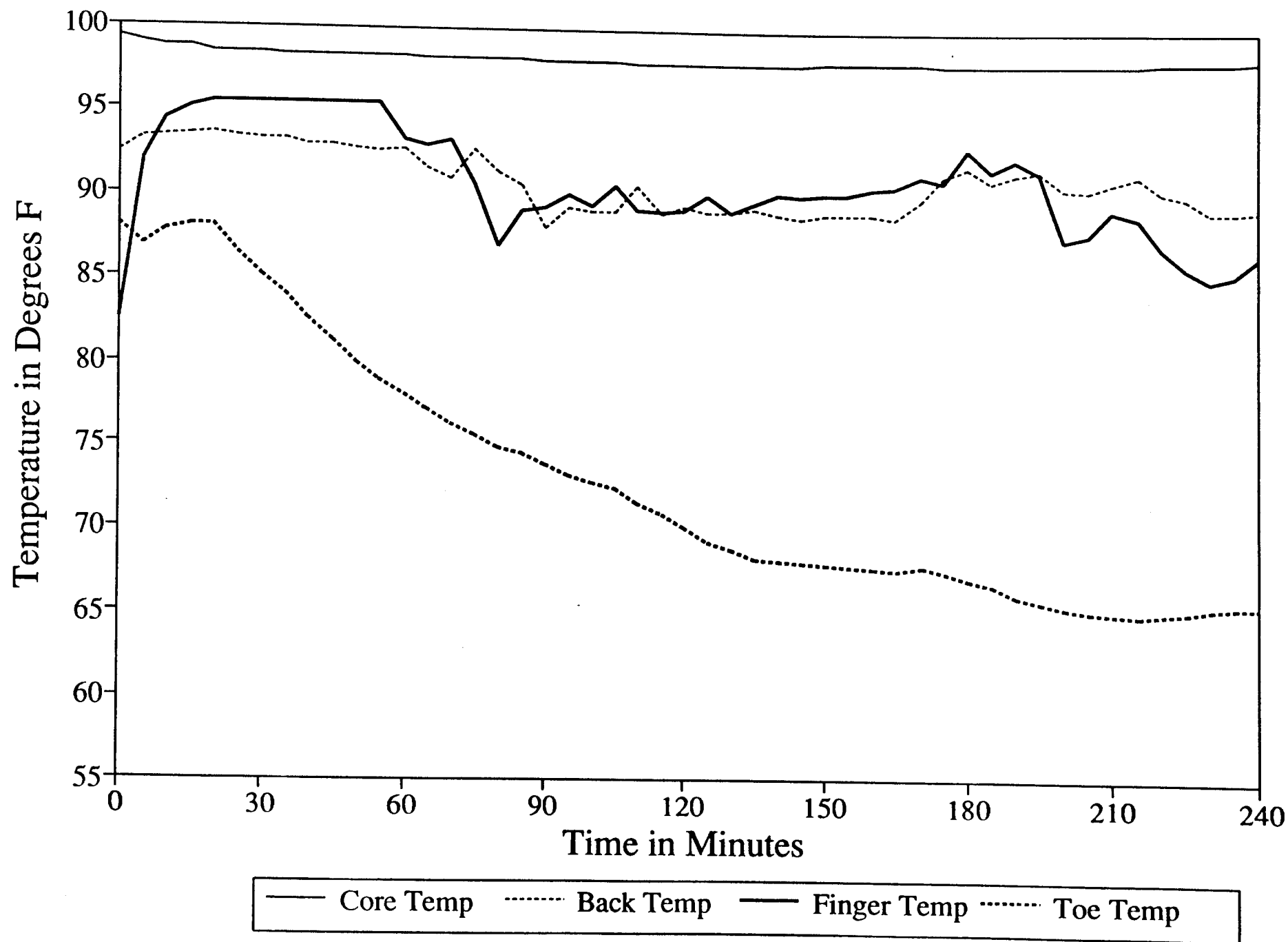


Figure C-22. Subject 10 in intermediate bag at 0 degrees F.

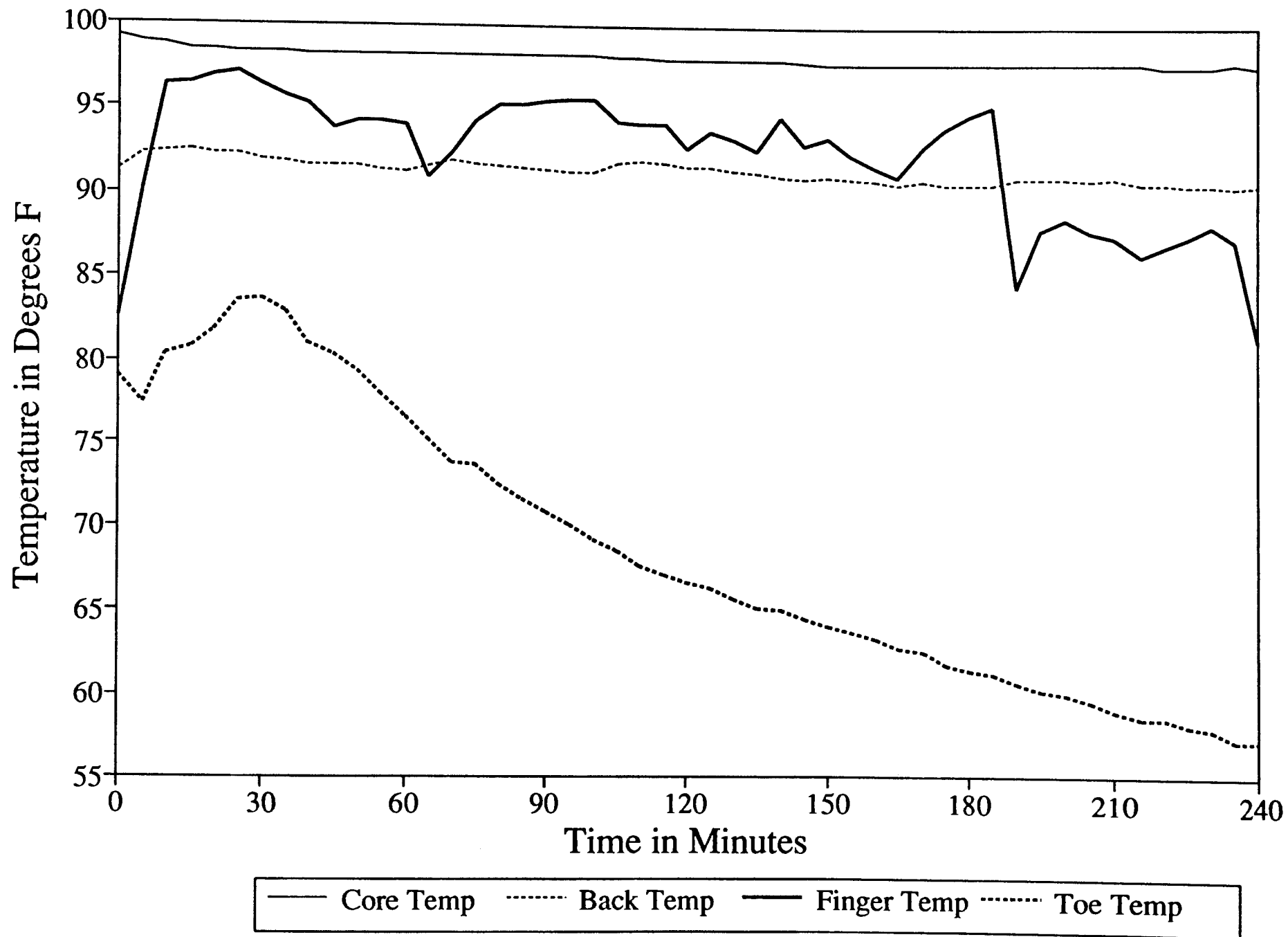


Figure C-23. Subject 11 in intermediate bag at 0 degrees F.

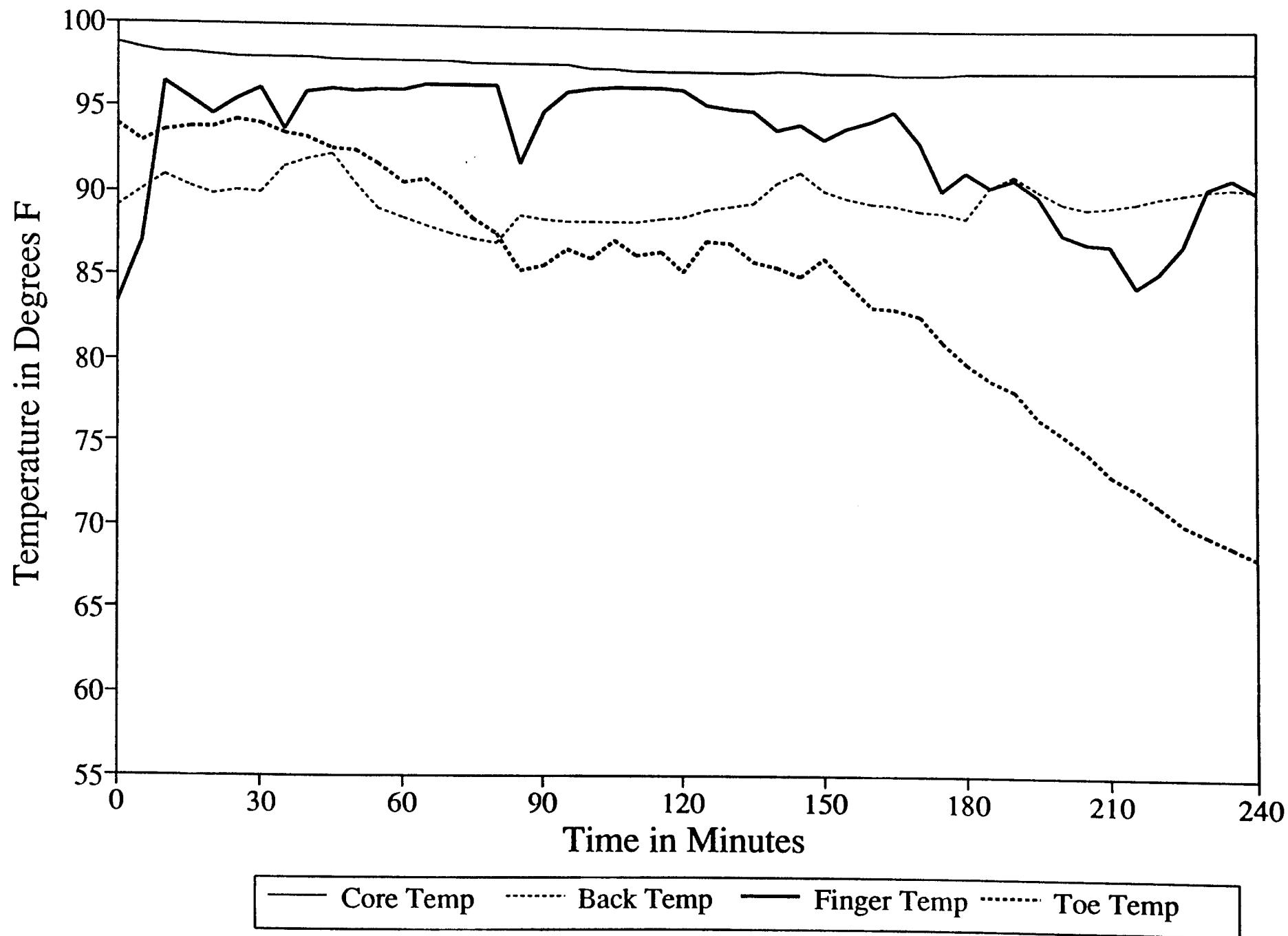


Figure C-24. Subject 12 in intermediate bag at 0 degrees F.

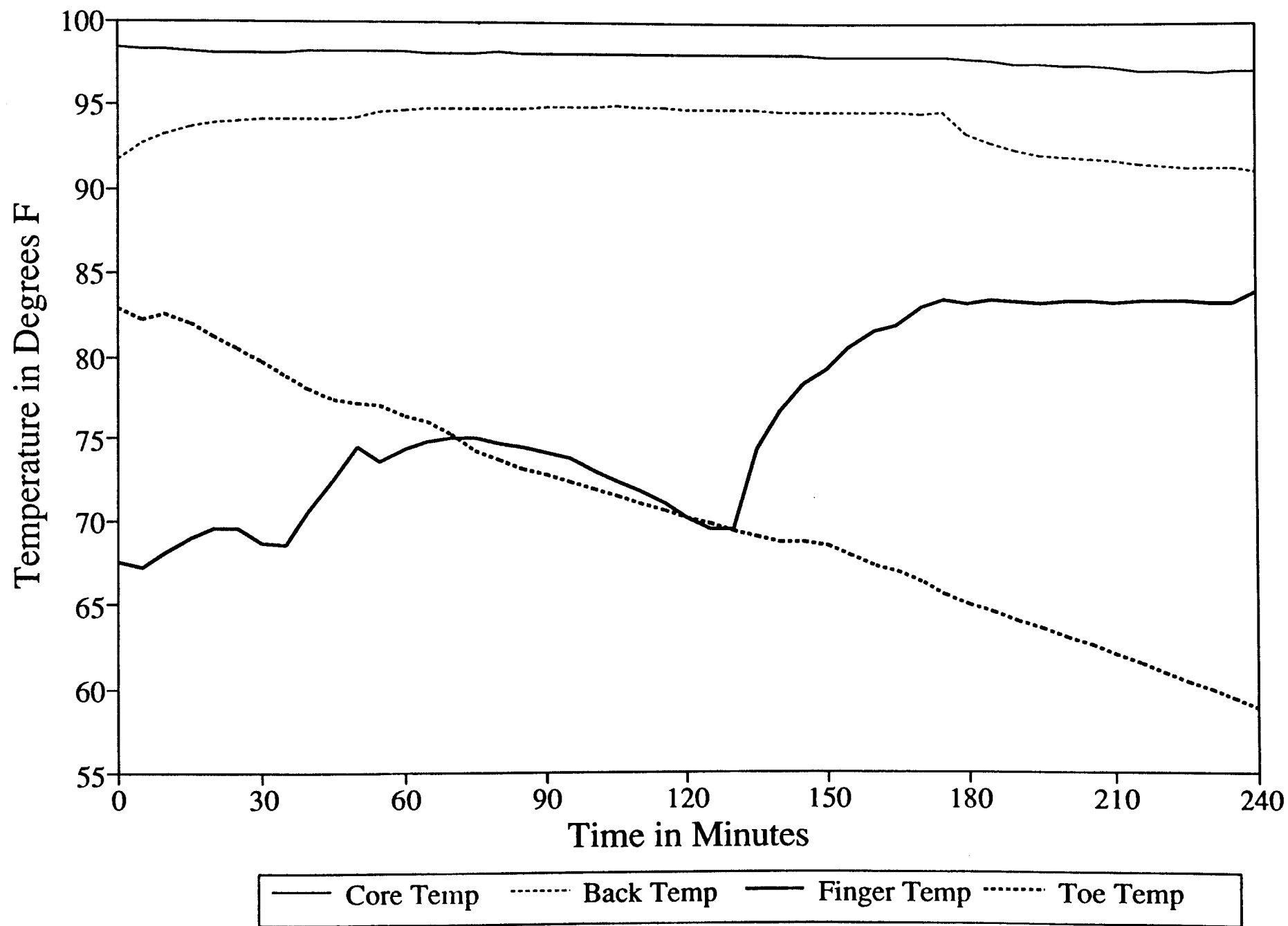


Figure C-25. Subject 1 in extreme cold bag at -30 degrees F.

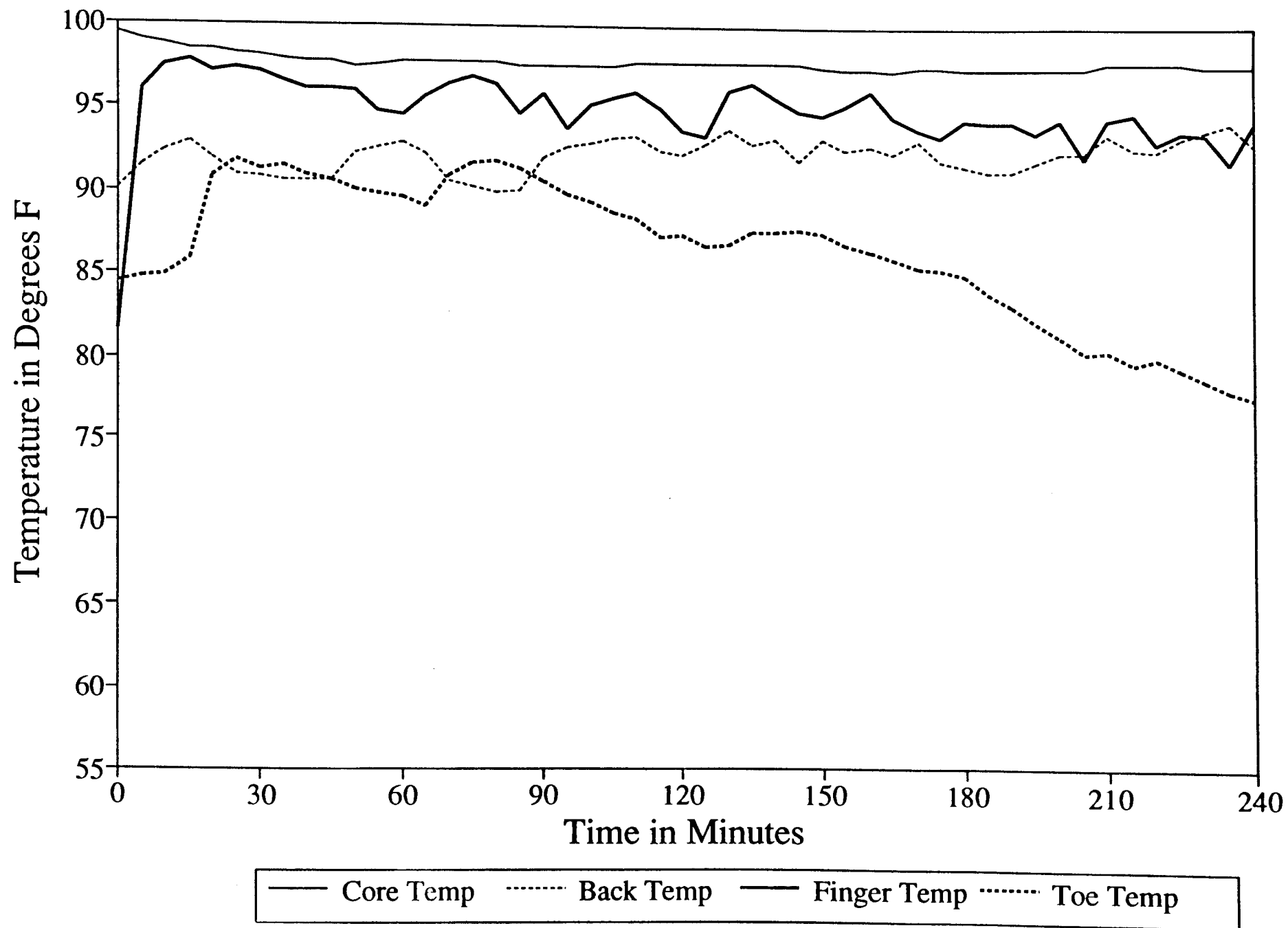


Figure C-26. Subject 2 in extreme cold bag at -30 degrees F.

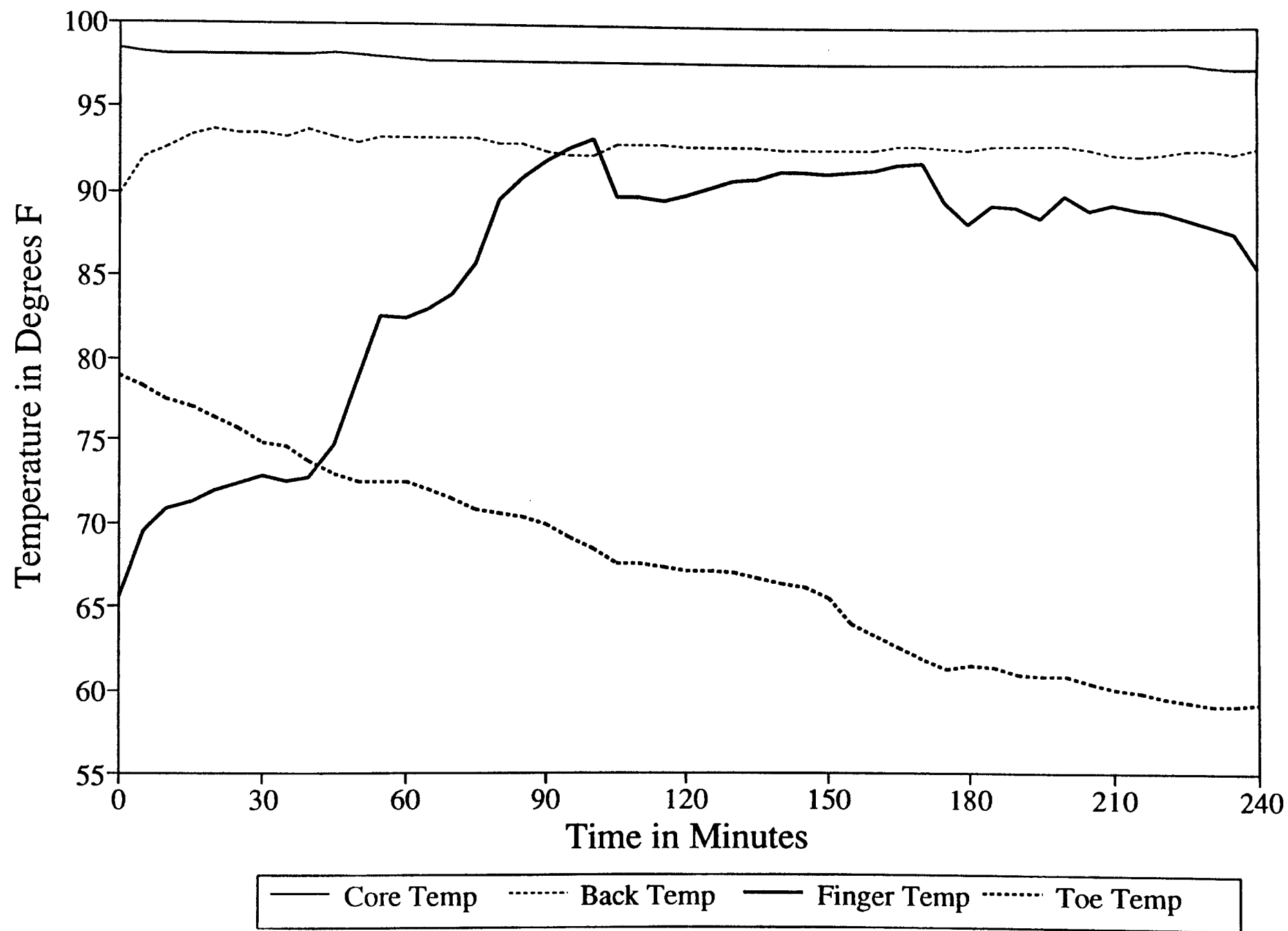


Figure C-27. Subject 3 in extreme cold bag at -30 degrees F.

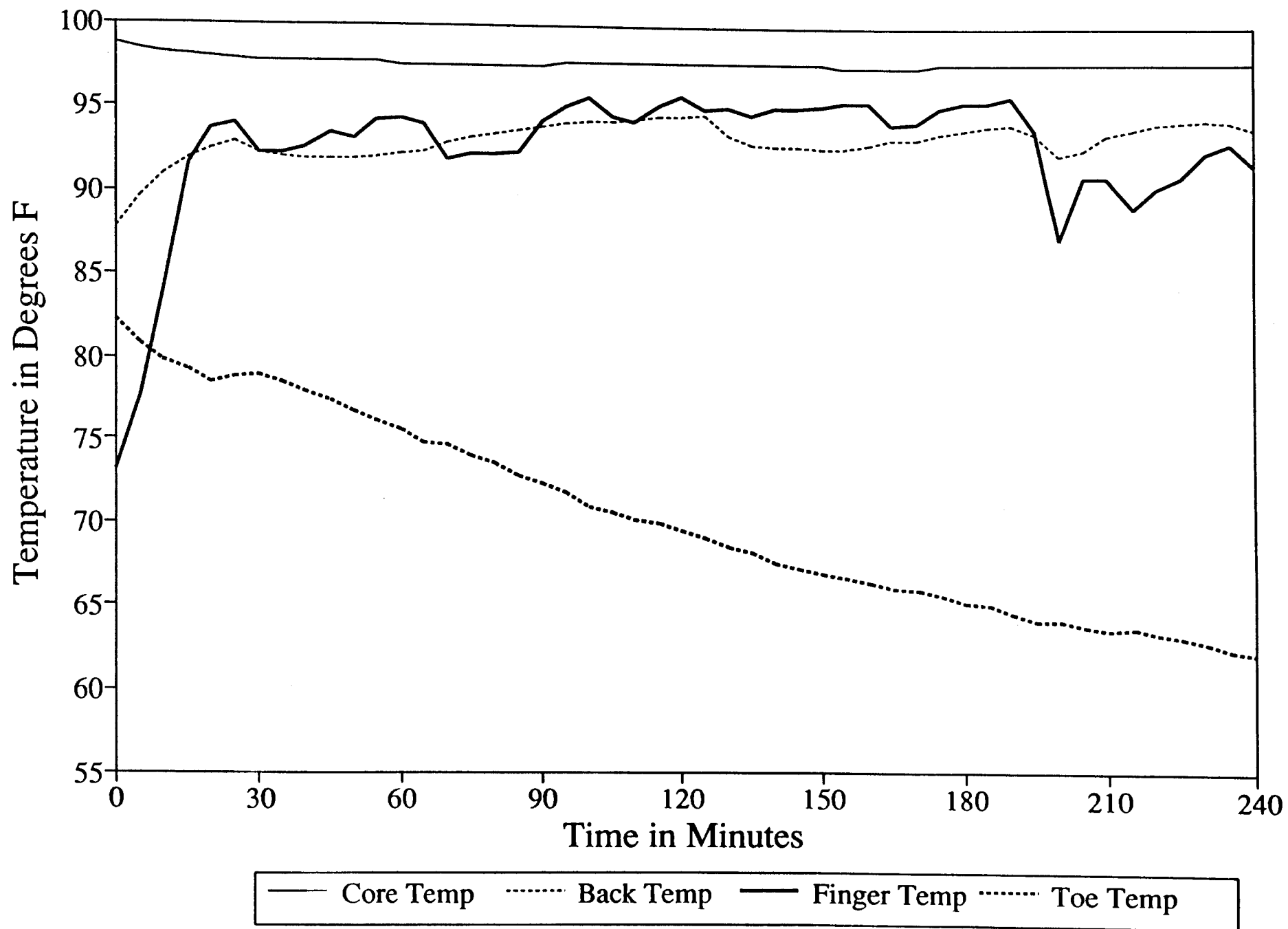


Figure C-28. Subject 4 in extreme cold bag at -30 degrees F.

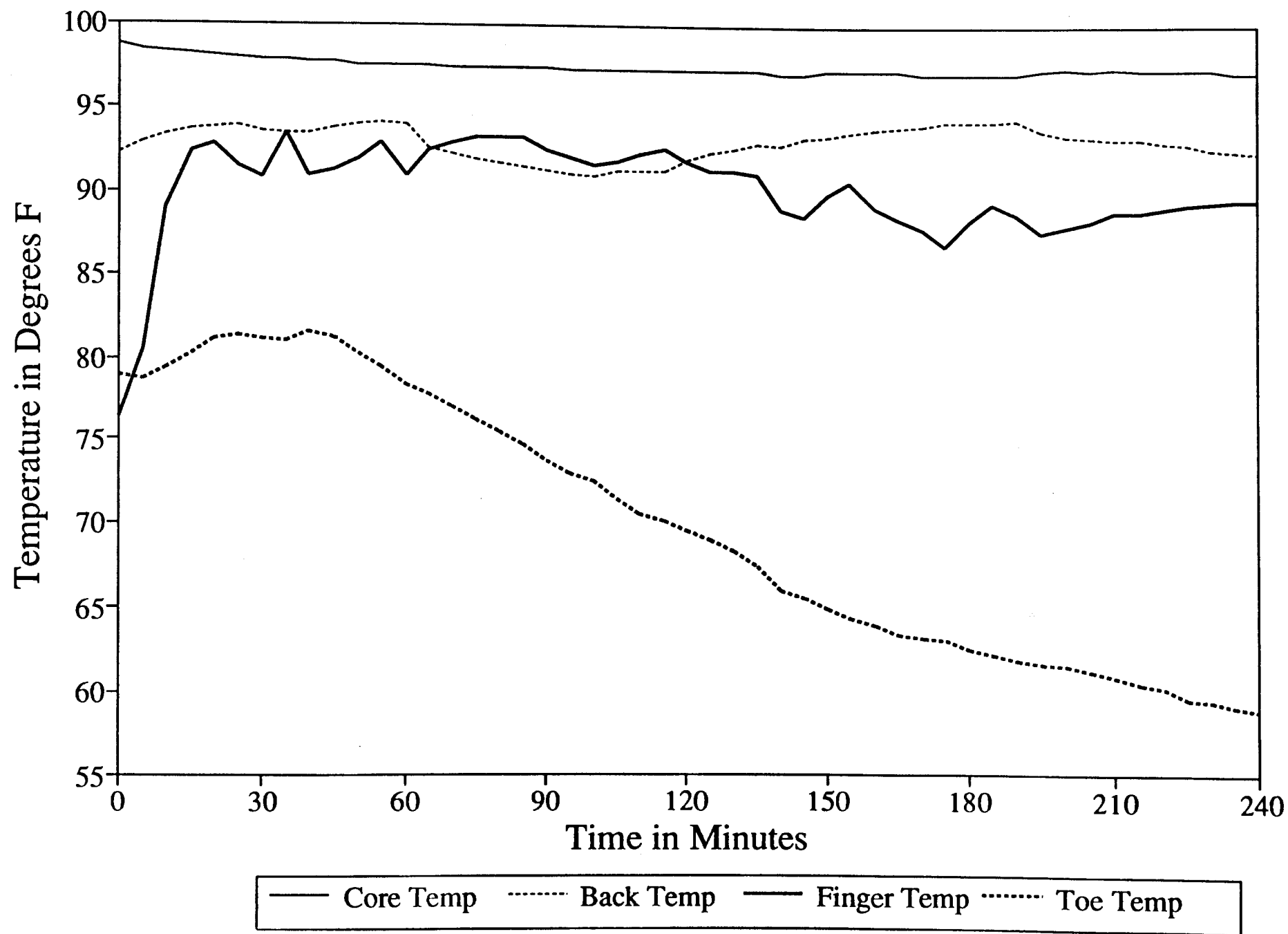


Figure C-29. Subject 5 in extreme cold bag at -30 degrees F.

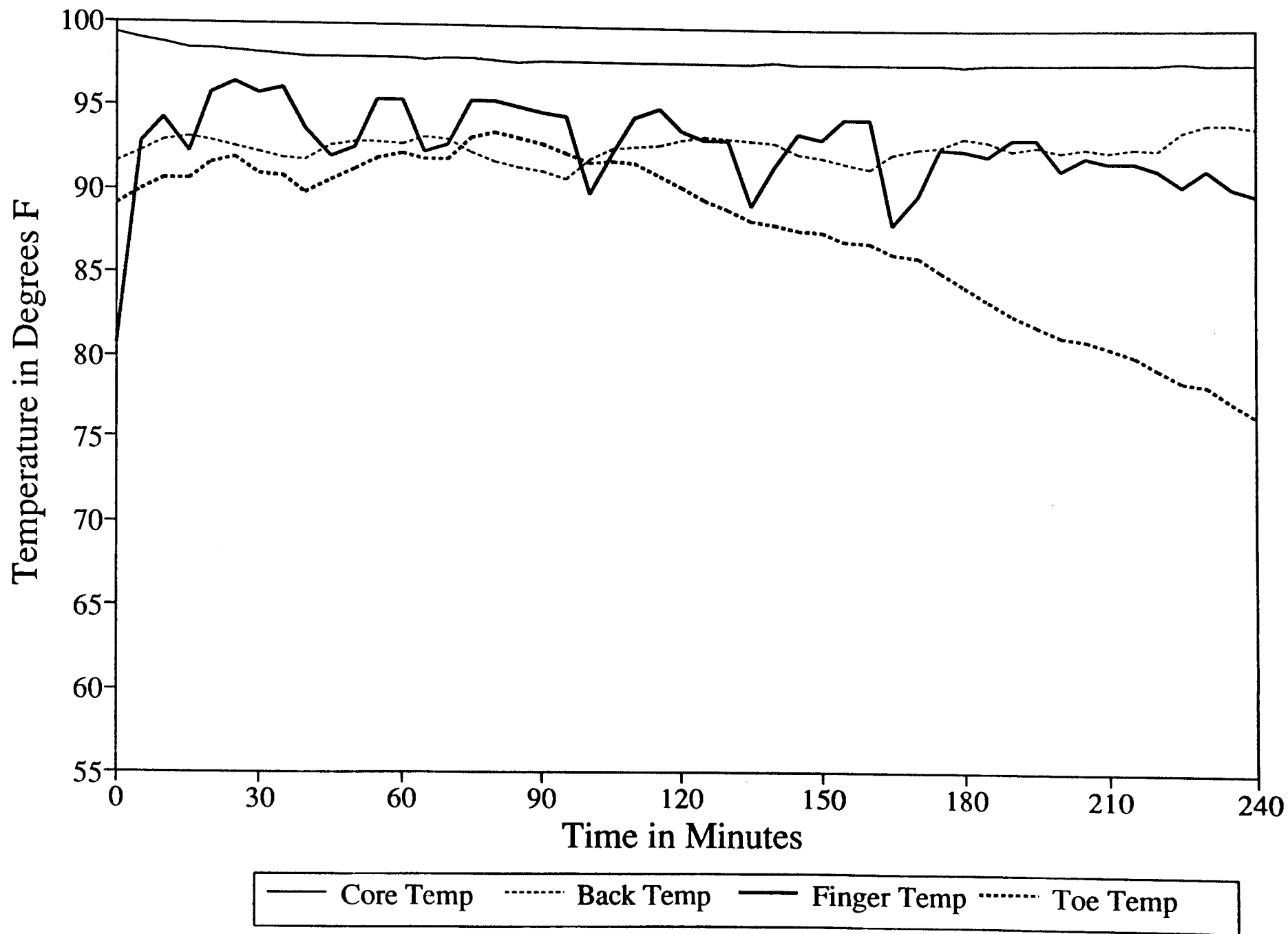


Figure C-30. Subject 6 in extreme cold bag at -30 degrees F.

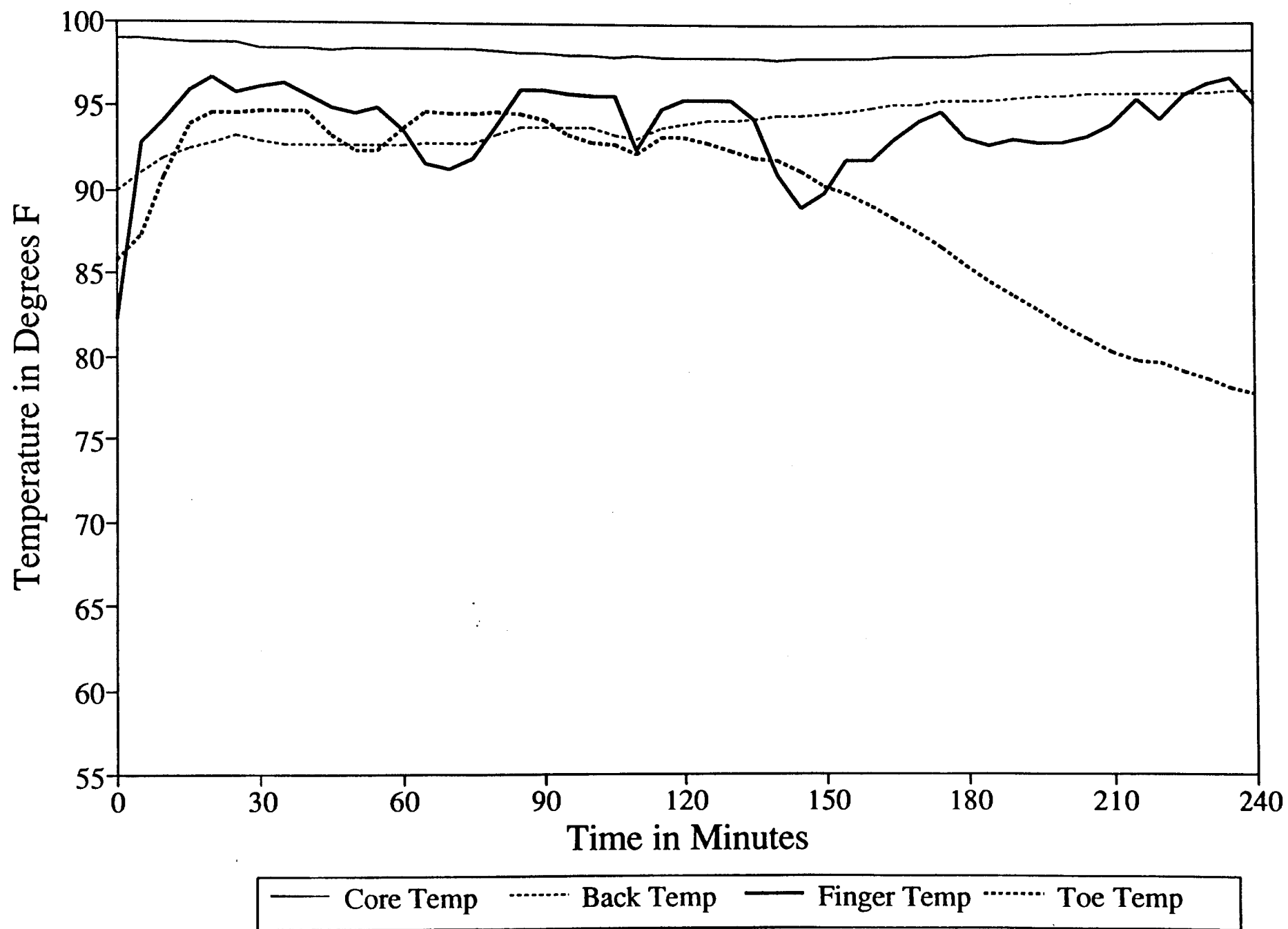


Figure C-31. Subject 7 in extreme cold bag at -30 degrees F.

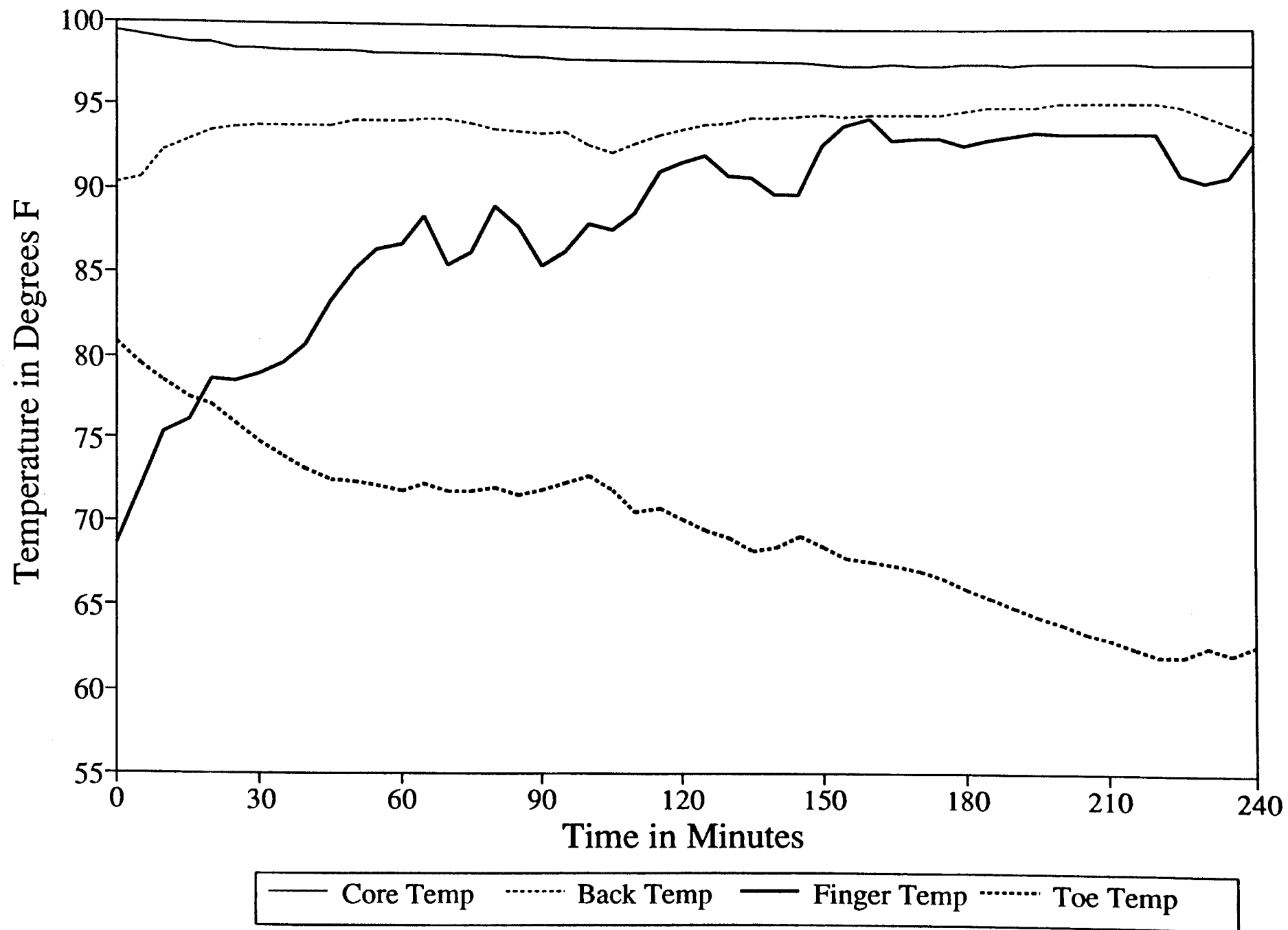


Figure C-32. Subject 8 in extreme cold bag at -30 degrees F.

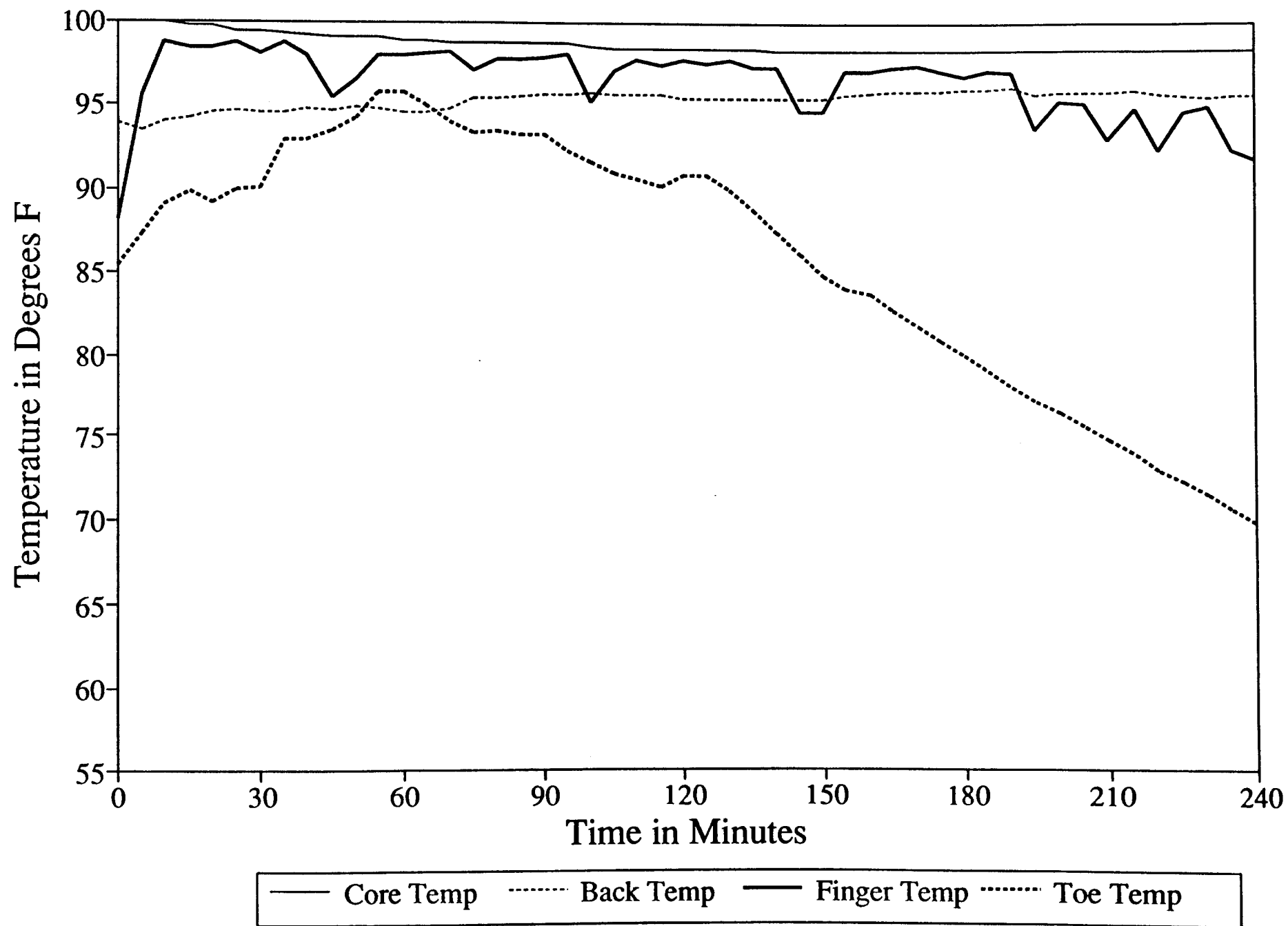


Figure C-33. Subject 9 in extreme cold bag at -30 degrees F.

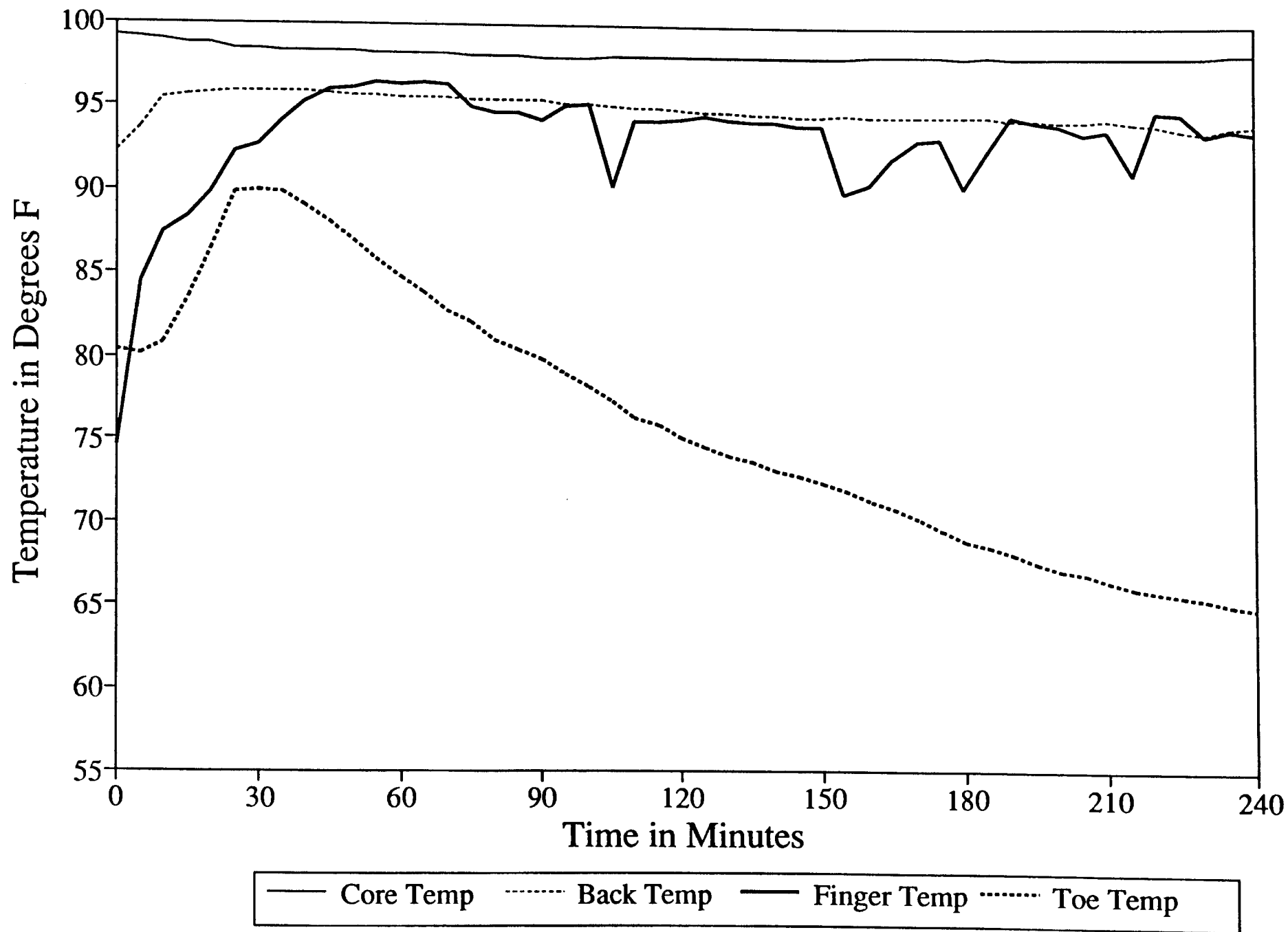


Figure C-34. Subject 10 in extreme cold bag at -30 degrees F.

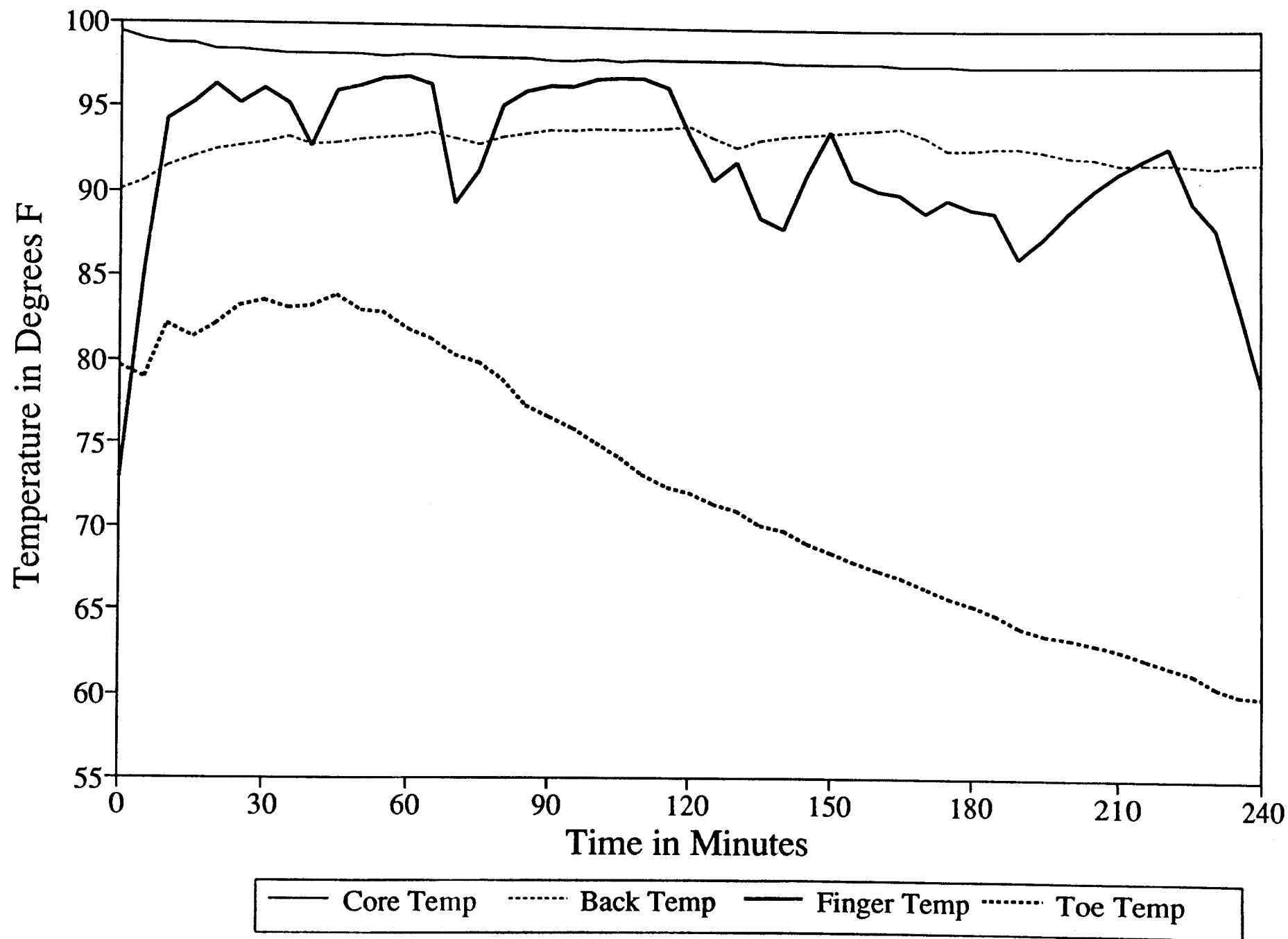


Figure C-35. Subject 11 in extreme cold bag at -30 degrees F.

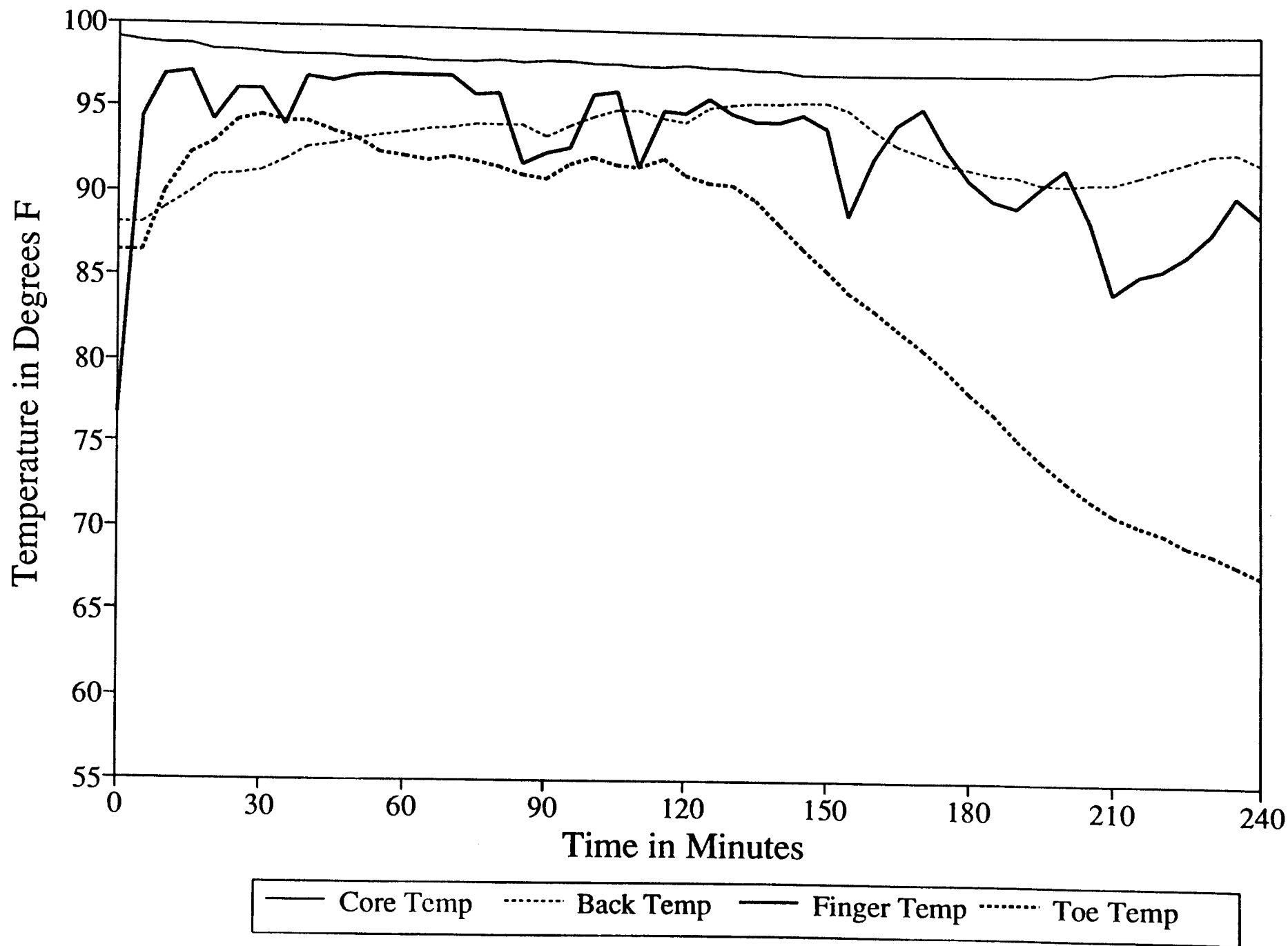


Figure C-36. Subject 12 in extreme cold bag at -30 degrees F.